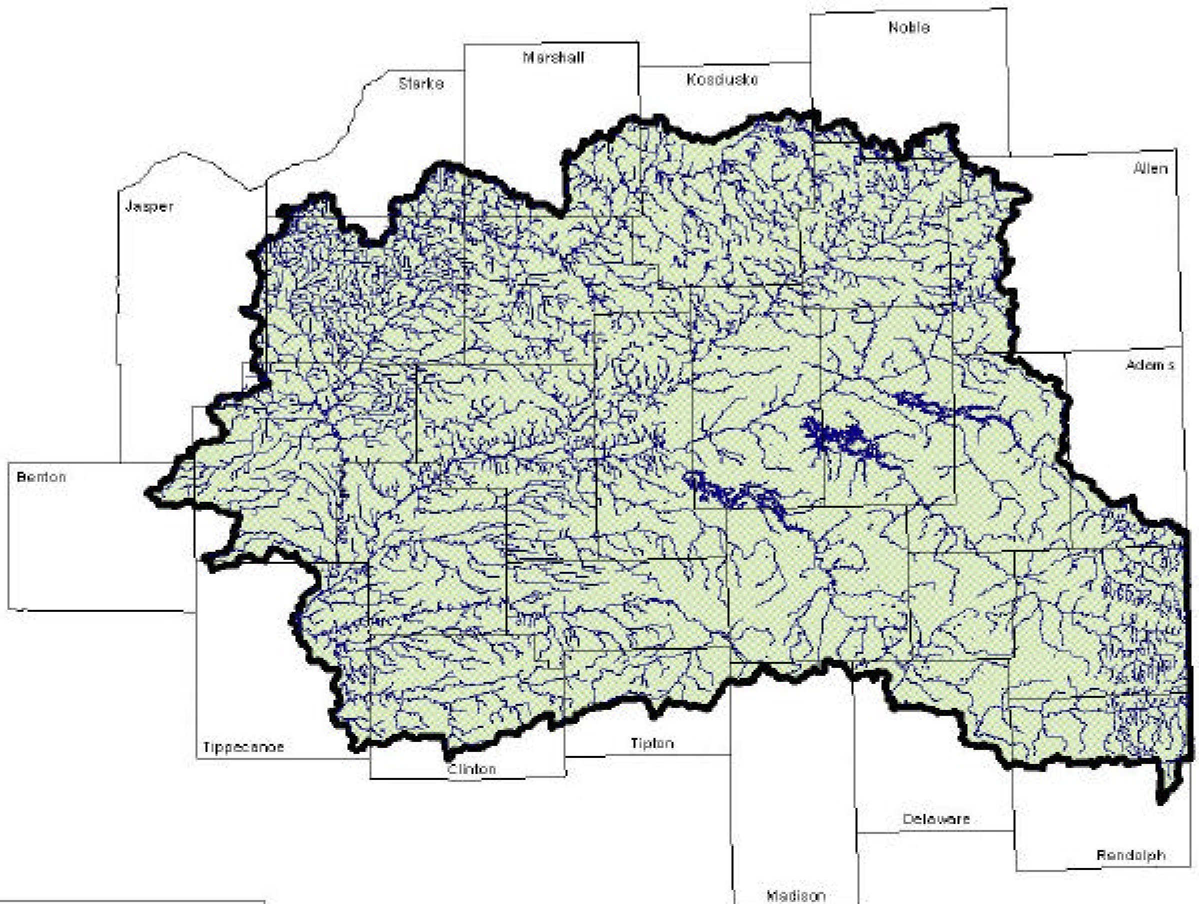
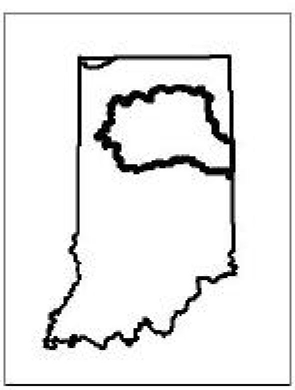
Trend Analysis of Fixed Station Water Quality Monitoring Data in the Upper Wabash River Basin 1998





INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER QUALITY
ASSESSMENT BRANCH
SURVEYS SECTION

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TRENDANALYSIS OF FIXED STATION WATER QUALITY MONITORING DATA IN THE UPPER WABASH RIVER BASIN 1998

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Executive Summary

In accordance with the Assessment Branch Monitoring Strategy, the Upper Wabash River Basin was the focus of sampling for 1998. In this report, the Fixed Station data from the Upper Wabash River Basin was analyzed using various means to look for trends and Water Quality Standards violations. The focus of the Fixed Station Program has been on the major rivers of the state, therefore it was logical to continue to use these sites as targeted locations, particularly since a wealth of historical data exists from many of these sites.

In the Upper Wabash River Basin a total of 372 Fixed Station water samples were collected for analysis of nine Total Recoverable Metals :arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc. Out of 2,976 discrete analytical tests, 100 exceeded values for stream standards based on the Chronic Aquatic Criteria. Only four sites also exceeded the Acute Aquatic Criteria. Most of these 100 values were for Lead and Mercury.

With respect to the nutrient parameters that were sampled and examined, the upper reaches of the main stem of the Wabash River had several sites that were higher than the median values of nutrient parameters derived from the data set of the main stem as a whole. The median values of Phosphorus, Total Kjeldahl Nitrogen and Total Organic Carbon were 0.2 mg/L, 3.5 mg/L and 5.5mg/l, respectively.

The Wildcat Creek had numerous sites that were higher than 0.2 mg/L for phosphorus in the upper reaches. The Salamonie River had higher than (5.5mg/L) median values for Total Organic Carbon. The lower stretches of the Wabash River and Wildcat Creek demonstrated higher levels of Nitrate + Nitrite than the other tributaries. These levels were greater than 3.5 mg/L.

For temporal or seasonal trend analysis, Seasonal Kendall tests using the WQHYDRO statistical software were performed on water quality monitoring data from the Upper Wabash River Basin Fixed Station sites. Historical water quality data from 1959 to 1998 were examined. The metals and nutrient parameter values showed a high variability respect to trends specific to individual sampling sites. Chloride and Hardness values were shown to be, in general, statistically increasing on the Salamonie and Wabash River sites during the period from 1959 to 1978. During the period from 1989 to 1998, pH was shown to be increasing at most of the sites, while hardness and total solids are shown to be decreasing.

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INTRODUCTION

In April 1957, the Division of Sanitary Engineering, Indiana State Board of Health, established 49 sites for the biweekly collection of surface water samples for physical, chemical and bacteriological analyses. Various changes and improvements have been made since the program was first established. On April 1,1986, the Indiana Department of Environmental Management was created and the Office of Water Management (now known as the Office of Water Quality) assumed operation of the program.

In 1998, the Assessment Branch of the Office of Water Quality, Indiana Department of Environmental Management revised its Surface Water Quality Monitoring Strategy (referred to as the Monitoring Strategy) (IDEM 1998a). At that time it was determined that the Fixed Station Water Quality Monitoring Program should continue to play a key role in water quality assessment and to provide data for use both within and outside the Agency. It was also determined that the number of sampling sites or stations needed to be increased to meet these goals. At the start of 1998 there were 106 sites in the Fixed Station Water Quality Monitoring Program. As part of the revision, it was decided to increase the number of monitoring sites by an additional 53 sites. Seventeen of the new sites were added in 1998 with 12 of these located in the Upper Wabash River Basin. The sampling frequency at sites that were previously sampled quarterly was increased to once a month so that all sites in this program are now sampled monthly. This was done to produce a better data set for statistical analyses, which can be analyzed for a variety of concerns. The primary purpose of the Fixed Station Monitoring Program is to provide analytical data to aid with the water quality assessment of the major rivers of Indiana. For a more detailed description of the Fixed Station Monitoring Program see the IDEM documents; *Fixed Station (Ambient) Monitoring Program: Fact Sheet. rev March 2001* (IDEM 1998b) and *Indiana Water Quality Fixed Station Program 1998-Monitoring Station Records-Rivers and Streams* (Holdeman and Gibson 2002).

In order to understand water quality, the Federal Clean Water Act, Section 305(b) guidelines (USEPA 1997) call for trend analysis. In accordance with IDEM's Surface Water Monitoring Strategy, the Upper Wabash River Basin was the focus of water quality assessment in 1998.

Purpose and Scope

The Fixed Station Water Quality Monitoring data from the Upper Wabash River basin were analyzed using various means to look for trends in water quality and Water Quality Standards violations. For water quality trends both temporal and spatial distribution were examined. Since the focus of the Fixed Station Monitoring Program has been on the major rivers of the state, it was logical to continue to use these sampling sites as targeted fixed stations or locations, particularly since a wealth of historical data exists from many of these sites. On some of the larger rivers, sampling sites were already distributed spatially with a high enough frequency so as to give a fairly good representation of each of these rivers. In other areas, sites are sparse, but they are still useful to provide general ambient water quality data for use in modeling for the National Pollutant Discharge Elimination System (NPDES) permits. Fixed Station Sampling sites also provide representative data for the particular type of land use in the watershed upstream of the sampling site. The data from these sites also complement the data from the

Watershed Monitoring Program of the Surveys Section to give an over all view of the chemical and physical Water Quality for the study area. The Watershed Monitoring Program (IDEM 1998c) uses a statistically valid number of randomly selected sites throughout the selected study area.

The Thirty-five Fixed Station sites for the Upper Wabash River Basin are the subject of this report. The data from these sites are displayed in various ways in order to present a basic physical and chemical description of the rivers in the area targeted. Some basic environmental indicators and pollution parameters were examined. In addition, the data were examined relative to the Water Quality Standards and emerging trends were noted. Four common nutrient parameters were examined along with the most common metals that have the potential to pose problems. Several other parameters were measured, but not examined in this report. Due to time constraints, only parameters that were considered to be of the greatest concern were addressed here. Stream standards do not exist at this time for the nutrient parameters chosen for study. Because of this, median values from the nutrient parameter data sets from the main stem Wabash River were calculated and used as a relative guide to relate to values from the tributaries as well as specific areas of the main stem. Areas showing parameters with values higher than the main stem median values and or water quality standards exceedances are considered possible areas of concern in most cases. Graphs of box plots were used to display and compare the nutrient data. Water quality stream standards were used for metals comparisons. When enough data were available, monotonic trend tests accounting for seasonality were run on the data sets and the results displayed in tables. Graphs of the results that demonstrated the most change are presented in the Appendices. Not all graphs created in the analytical process were included in this report for the sake of economy.

In the future, as each basin delineated in the Monitoring Strategy is examined on a five year rotating basis, comparisons can be made giving a much clearer picture of the trends in the surface waters of the State. The Fixed Station Monitoring Program represents one part of the entire water quality picture and the results from this report should be viewed in relation to and within the context of the entire Monitoring Strategy.

METHODS AND MATERIALS

GEOGRAPHICAL AREA

The Upper Wabash River basin is defined by the Monitoring Strategy as the Wabash River and its tributaries from the Ohio State line downstream to below the confluence of the Wildcat Creek in Tippecanoe County. It includes the Salamonie, Mississinewa, and the Tippecanoe Rivers and Deer and Wildcat Creeks. Specifically, the following hydrologic units as defined by the United States Geological Survey, (USGS): 05120101, 05120102, 05120103, 05120104, 05120105, 05120106 and 05120107 cover the study area. A map of Fixed Station monitoring locations in the Upper Wabash area is presented in Figure 1 and a complete listing of the Fixed Station Monitoring sites with latitudes and longitudes is presented in Appendix A.

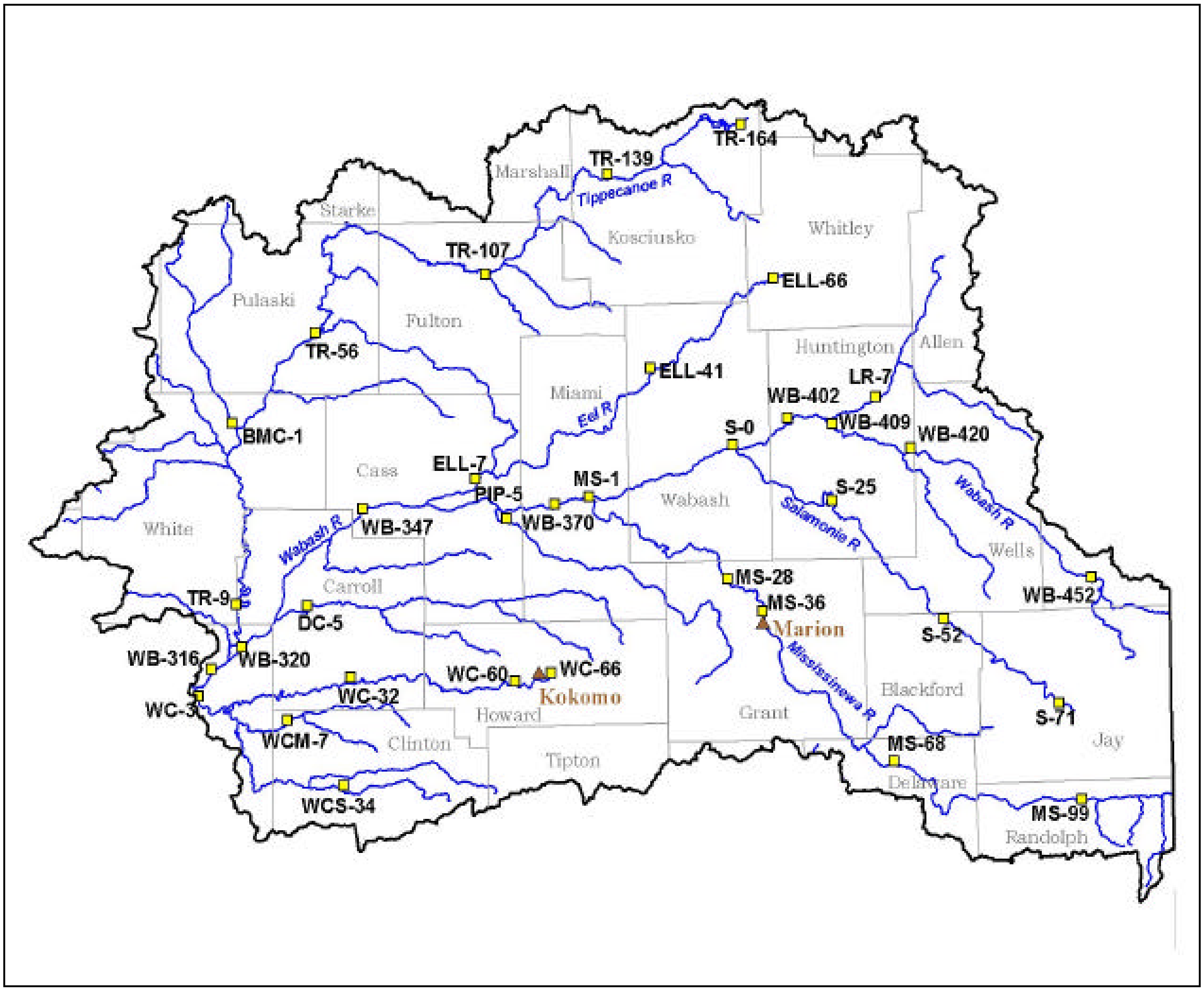

Figure 1 Fixed Station Sampling Sites in the Upper Wabash River Basin

SAMPLING PROCEDURES

The Surveys Section of the Assessment Branch, Office of Water Quality has established standardized sampling methodologies which are described in the document *Surveys Section Field Procedure Manual, Rev April 2002* (Beckman 2002) to which the reader is directed for a more detailed description about sampling procedures. The following discussion is specifically oriented to the Fixed Station Program procedures.

Ambient water sampling was initially conducted from various types of bridges in order to permit sample collection from the main channel of the stream. Newer sampling methods have since been adopted and many fixed station locations are now sampled by wading.

Grab samples for laboratory analyses were collected from the visual center of the stream flow. A special sampler was designed to hold the sample bottles and thereby collect the water samples directly rather than using an intermediate container. When conditions permitted, water samples were collected by wading into the stream and filling the sample bottles by hand. This was very useful on smaller streams without adequate depth for the sampling device. Latex gloves were worn by the sample collector at all times during the handling of the sampling device or the sample bottles. The sampling device was rinsed with de-ionized water after each use and placed in a plastic bag for transport to the next site. Preservatives were added to appropriate samples. All sample bottles were rinsed externally with de-ionized water and kept in ice filled coolers for transport to the water laboratory. Reagent blanks, duplicate samples, and matrix spike samples were submitted as required by the Sampling Work Plan (Holdeman 2002).

QUALITY CONTROL

The following QA/QC guidance for field blanks and duplicates was applied. Duplicate water samples were taken at a rate of six percent of the total sites sampled. Each crew chief was responsible for taking the required duplicate samples as generated randomly from the Assessment Branch AIMS database. This was performed during each monthly round of sampling. Sample bottles and preservatives certified for purity were used. One set of field blanks was prepared and carried with each sample set. This blank set was preserved at the last sample location. Matrix spike and matrix spike duplicate samples were prepared and tested by the laboratory at a rate of ten percent as required by the Sampling Work Plan (Holdeman 2002).

WATER QUALITY PARAMETER ANALYZED

Water samples were collected for general chemistry, metals, nutrients, and bacteriological analyses. At some sites uncommon parameters such as phenol and radiochemistry samples were collected. Bacteriological samples were only collected when they could be delivered to the analytical laboratory within 6 hours. Sampling routes for the program were planned to minimize both travel expense and holding times for samples prior to laboratory delivery.

Water quality parameters used as indicators of water quality are not limited to the constituents that are known to be a problem, but also includes constituents that can potentially become a problem. The last full review of water quality parameter coverage for the Fixed Station Monitoring Program was performed in 1986 (IDEM 1986). That report includes a discussion of parameters that were collected at sites in operation prior to 1986, as well as new parameters added to the Fixed Station Monitoring Program.

Amendments to parameter coverage selection at individual stations were based on:

1) A review of data from 1979 to 1985 based on state standards and/or recommended criteria;
2) Established and/or recommended water quality standards;
3) Stream use designations;
4) Data needs within the agency; and
5) Requirements by other agencies.

An explanation of changes in sampling for additional parameters can be found in the 1986 report.

Twelve new Fixed Station sites were added to the Upper Wabash Basin in 1998. The parameter coverage selection on these new sites was based on the set of parameters used in the Synoptic surveys performed in 1996-97. A general discussion of this set of parameters can be found in the reports developed from those surveys (Holdeman et al. 1998a-c, 1999).

FIELD PARAMETERS ANALYZED

Field tests for dissolved oxygen, temperature, pH, specific conductance, and turbidity were conducted each time a water sample was collected. A HydroLab H_20^{TM} multi-probe transmitter sonde, with a stirring unit, and Scout 2 ™ display unit were used for these tests. Water samples were collected with a polyethylene bucket from the center of the flow and poured with minimal aeration into a specially designed container (PVC tube). The probe unit was then submerged in the tube and readings taken. All pieces of equipment were rinsed with sample water prior to sample collection and testing. Ambient weather conditions at the time of sampling were noted on the field sheet.

The HydroLab™ sondes were calibrated in the office on a routine basis. Comparative field testing for dissolved oxygen, pH, and turbidity were done at least once per day during fieldwork. The Winkler Titration method was used for dissolved oxygen comparisons. A calibrated Cole-Parmer Model 5985-80 Digi-Sense™ pH meter and a Hach 2100-P turbidimeter were used to check calibration for those paramenters.

DATA ANALYSIS AND PRESENTATION

Appendix B shows the Upper Wabash River Fixed Station water quality violations. Several methods of displaying and interpreting data were used in order to analyze trends over time, emerging trends and upstream/downstream trends in stream segments. Graphic presentation of this information is presented in Appendices C - H. It should be noted that due to space constraints, only representative graphs are included in this report. Graphs were selected that most dramatically illustrate a particular relationship. Multiple two-dimensional line plot graphs, box and whiskers plots and histograms were used in order to help view and interpret the data. WQHYDRO (Aroner 1994), a statistical analysis program that takes into account seasonality, also was used to show trends over time in the historical data (Figure 2). A complete listing of the data can be found in Holdeman and Gibson (2002).

One method of displaying data in this report is the box and whiskers plot. The box portion of the plot encloses the 25th to 75th percentile (the center portion of the data). This range is referred to as the *interquartile range*. The median (50th percentile) is represented by a small square located within the box. Data values less than the 25th percentile and greater than the 75th percentile are represented by lines called whiskers extending from the top and bottom of the box. These whiskers extend up to 1.5 times the interquartile range from the top and bottom of the box. Data points include outliers, represented by a "o", and extremes, represented by a "*". Outlier and extreme values are greater than 1.5 times the interquartile range from the top and bottom of the box.

Another method for displaying data is to use histograms. Histograms divide a data set or population into groups by numeric value. These groups are represented on the x-axis. Each group is defined by two numbers; a lower number to the left, and an upper value to the right. The rounded bracket on left (the exclusive bracket) indicates the group does not include the value while the squared bracket to the right (the inclusive bracket) indicates the group includes this value. The number of observations in each

Seasonal Kendall Test
Formulas and Explanation

The Seasonal Kendall test is derived from the Mann-Kendall Test. The Mann-Kendall test has the null hypothesis that the variables are random with respect to time. A stepwise iterative comparison is made from one observation to the next. A score of +1 is awarded if the difference from one data point to the next increases. Likewise, a score of -1 is awarded if the difference from one point to the next decreases. Below is the *S* test statistic.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

Therefore, as *S* becomes larger in magnitude, either positive or negative, the significance of the test increases. If *S* becomes large enough, the null hypothesis is disproven, and it is concluded that a trend exists. The statistical significance of *S* is dependent on the variance. The variance for this test is defined below.

$$Var(S) = \{n(n-1)(2n+5) - \sum_{j=1}^{p} [t_j(t_j-1)(2t_j+5)]\} / 18$$

t_j is the number of observations in a given tie. This term drops out if there are no ties.

The S statistic and the Variance are used to calculate the *Z* score.

$$Z=(S-1)/[Var(S)]^{1/2} \text{ if } S>0$$
$$Z=0 \text{ if } S=0$$
$$Z=(S+1)/[Var(S)]^{1/2} \text{ if } S<0$$

When the *Z* score exceeds the statistically critical value, the null hypothesis is rejected leading to the conclusion that a trend exists.

The Mann-Kendall is a monotonic test, not taking into account seasonality. The Seasonal Kendall test divides the data into like *seasons*. *Seasons* are defined by the user of the test as either months or quarterly seasons of the year. Intermediate statistics, S_i, are calculated for each of the user defined seasons in the same manner as the formula for the Mann-Kendall Test. The influence of seasonality is eliminated since observations are only compared to observations from the same season. The S_i statistic for each season are then summed to yield a global statistic S_T. Likewise, a variance is calculated for each of the S_i statistics and summed to yield the statistic $Var(S_T)$.

The *Z* score for the Seasonal Kendall Test is listed below.

$$Z=(S_T-1)/[Var(S_T)]^{1/2} \text{ if } S_T>0$$
$$Z=0 \text{ if } S_T=0$$
$$Z=(S_T+1)/[Var(S_T)]^{1/2} \text{ if } S_T<0$$

For the Seasonal Kendall test, if the *Z* score exceeds the critical value, the null hypothesis is rejected and the conclusion is made that a trend exists.

(After Aroner, 1994 p152)

Figure 2 Derivation of the Seasonal Kendall Test

group are indicated by the height of each of the bars in the histogram. Further, a percentage that each group contains of the entire data set is found above each of the bars. A normal curve is overlaid on the histogram to show how the data approximates a normal distribution. The apex of this curve is the mean of the data set (StatSoft 1998).

RESULTS AND DISCUSSION

TRACE METALS

Nine heavy metals were analyzed in the waters from the basin as Total Recoverable: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. Lead and Mercury are discussed separately due to concerns about the reliability of detection and quantification limits. The remainder of seven metals are discussed as a group in the section following lead and mercury.

Lead and Mercury Analysis

Lead and mercury analyses were performed on all 1998 Fixed Station water samples collected. During the course of that data analysis, concentrations of some samples were noted as exceeding Water Quality Standard's (Table 1). Since the time of initial analysis of the 1998 data set, IDEM analytical techniques have become more sophisticated. New techniques have brought into question the level of accuracy of the 1998 Fixed Station lead and mercury data. <u>Due to the uncertainty of low level test results in the 1998 data set, it is recommended that lead and mercury results from the 1998 data set not be used for IDEM decision making purposes.</u>

Past lead analyses performed by the laboratories in support of the IDEM Fixed Station (Ambient) Monitoring Program utilized EPA Test Method 200.7. Method 200.7 was unsuited for very low- level lead determinations necessary for IDEM water quality assessment purposes. This is because the Test Method 200.7 is only capable of achieving a Limit of Detection (LOD) of 10 ìg/L and Limit of Quantitation (LOQ) of 32 ìg/L. Furthermore, EPA Test Method 200.7 prescribes concentrating the water sample by a factor of 2 (100mL to 50mL) during sample preparation which doubles the effect of any contamination or matrix interference which could lead to erroneous lead results. Of further note, the inductively coupled plasma (ICP) instrument utilized by the Contract Laboratory for EPA Test Method 200.7 is and ICP with the plasma oriented axially. Although this axial configuration is very sensitive relative to radial ICP instruments, it is very susceptible to molecular interference because the cool zone of the plasma where recombination occurs as well as the normal viewing zone (hot zone) are viewed by the instrument optics and detector. Radial ICP instruments lack the sensitivity of an axial ICP, but they view only the normal viewing zone of the plasma which make them less susceptible to interference than the axial ICP instrument.

Current Fixed Station lead analyses are conducted according to EPA Test Method 200.8. Method 200.8 uses Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) which is a more sensitive test than EPA Test method 200.7, the method used in 1998. Method 200.7 uses Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES).

The analytical superiority of EPA Test Method 200.8 over EPA Test Method 200.7 was recently

Table 1 Descriptive Statistics for Wabash River Fixed Station Sites - 1998 Data Set

	Nitrate + Nitrite-N	Total Phosphorus-P	Total Kjeldahl Nitrogen-N	Total Organic Carbon-C
Valid N	156	156	120	108
Mean	3.660	0.258	1.228	6.131
Confidence -95%	3.199	0.237	1.114	5.781
Confidence +95%	4.121	0.279	1.343	6.481
Median	3.600	0.230	1.100	5.600
Sum	570.900	40.270	147.400	662.100
Minimum	0.100	0.080	0.400	3.500
Maximum	18.000	0.850	3.400	12.000
Lower Quartile	1.550	0.170	0.800	4.700
Upper Quartile	4.900	0.335	1.550	7.300
Range	17.900	0.770	3.000	8.500
Quartile Range	3.350	0.165	0.750	2.600
Variance	8.494	0.018	0.401	3.367
Std.Dev.	2.914	0.132	0.633	1.835
Standard Error	0.233	0.011	0.058	0.177
Skewness	2.269	1.462	1.456	0.957
Std.Err. Skewness	0.194	0.194	0.221	0.233
Kurtosis	8.080	2.831	2.382	0.519
Std.Err. Kurtosis	0.386	0.386	0.438	0.461

Table 2 Descriptive Statistics for Wabash River Fixed Station Sites – 1991 - 1998 Data Set

	Nitrate+ Nitrate-N	Total Phosphorus-P	Total Kjeldahl Nitrogen-N	Total Organic Carbon-C
Valid N	1188	1186	394	135
Mean	3.916	0.235	1.205	6.014
Confidence -95.000%	3.604	0.225	1.146	5.690
Confidence +95.000%	4.227	0.246	1.264	6.338
Median	3.500	0.200	1.100	5.500
Sum	4651.900	278.837	474.740	811.900
Minimum	0.100	0.030	0.100	3.100
Maximum	170.000	3.400	7.900	15.400
Lower Quartile	1.800	0.150	0.900	4.700
Upper Quartile	5.100	0.280	1.400	6.800
Range	169.900	3.370	7.800	12.300
Quartile Range	3.300	0.130	0.500	2.100
Variance	29.918	0.034	0.360	3.630
Std.Dev.	5.470	0.184	0.600	1.905
Standard Error	0.159	0.005	0.030	0.164
Skewness	23.763	9.203	4.328	1.650
Std.Err. Skewness	0.071	0.071	0.123	0.209
Kurtosis	717.163	144.687	40.006	4.251
Std.Err. Kurtosis	0.142	0.142	0.245	0.414

described in an internal IDEM technical memorandum.[1]

Only Fixed Station lead determinations which utilize EPA 200.8 performed after January 1, 2001 will be used to determine Water Quality Standard violations to assure the necessary accuracy of IDEM decision making processes (i.e., water quality assessments, modeling, etc.).

Concerning mercury determinations IDEM recently published mercury data using clean sampling techniques, EPA Test Method 1669 ("Clean Hands, Dirty Hands"), and ultra-clean analyses techniques for mercury, EPA Test Method 1631, Cold Vapor Atomic Fluorescence Spectroscopy (CVAFS) (Ratcliff and GhiasUddin 1999). A pilot study showed ambient water column mercury concentrations to be nearly 100 times lower than the levels found in 1998 using conventional sampling techniques and the conventional and less sensitive test method, SM 3112 B, Cold Vapor Atomic Absorption Spectroscopy (CVAAS). IDEM began a two year statewide trace metals project in 2001 (IDEM 2001) which utilizes clean sampling techniques and ultra-clean analyses in order to more accurately quantify ambient water column mercury concentrations throughout the State. This data however, will be subjected to peer review before it is published and was not available for this report. Future mercury sampling and analysis test method selection decisions will be made subsequent to the publication of this special statewide trace metals project report.

One interesting side note to the analysis of the metals data was the Aseasonal@ timing of the majority of the total lead exceedances. Figure 3 depicts the exceedances by month for both the Upper Wabash Basin and the statewide exceedances noted in the fixed station monitoring program.

Arsenic, Cadmium, Chromium, Copper, Iron, Nickel, and Zinc Analysis

Heavy metals may be introduced into the water from both natural and human activities. Metals can be introduced into surface water from soil and crustal erosion, industrial and municipal wastewater effluents, atmospheric deposition, and runoff resulting from land use activities such as agriculture, silviculture, and mining. Once metals are introduced into the water, several processes can happen depending on the type of metal released. Heavy metals may be dissolved in water, become volatilized to the air, or become suspended and then deposited in streambed sediment.

Toxicity of most heavy metals to aquatic life is a function of both the metal concentration and the hardness (as calcium carbonate, CaCO3) present in the water. As hardness decreases and metal concentrations increase, toxicity increases.

[1] Internal Office Memorandum, Non-EPA Method 1669, IDEM/100/29/496/183/2000, December 4, 2000

Figure 3 Lead Exceedances by Month

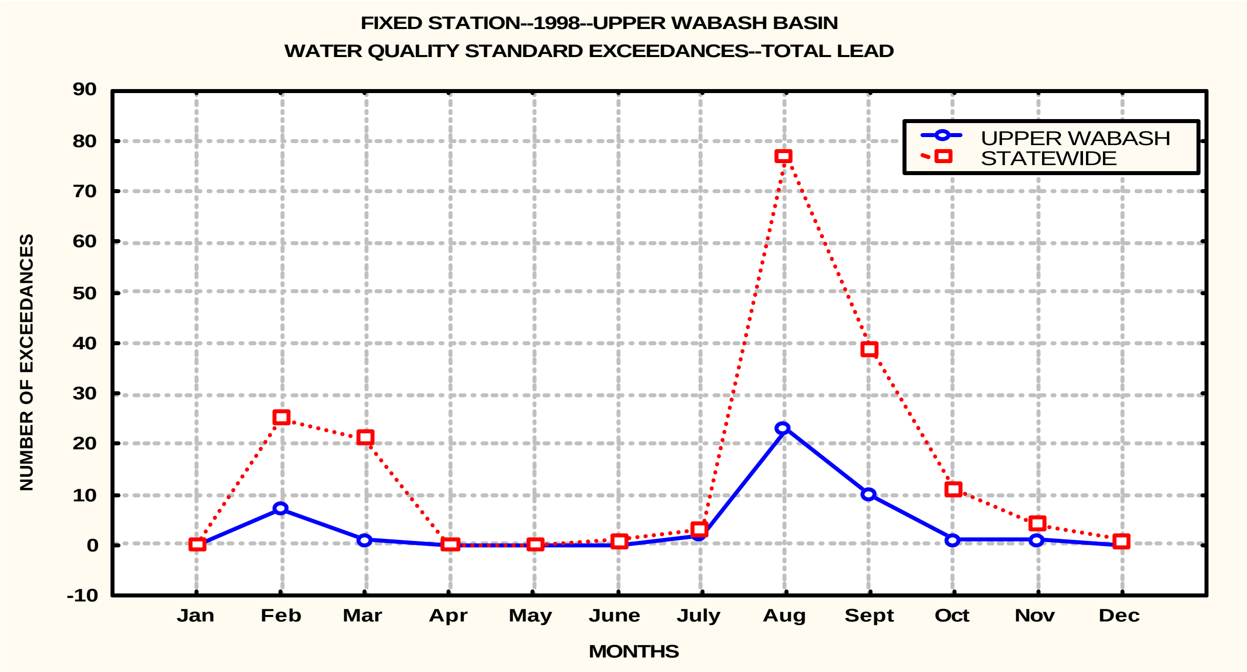

Table 3 lists the State of Indiana water quality criteria at various hardness levels for selected metals analyzed in this study. The maximum value is expressed as the Acute Aquatic Criterion (AAC). The Chronic Aquatic Criterion (CAC) is generally lower than the AAC, but is established as a 4-day average exposure limit.

Table 3 Metals Criteria for the Protection of Aquatic Life

Hardness	Cadmium		Copper		Lead		Nickel		Zinc	
as $CaCO_3$	CAC	AAC	CAC	AAC	CAC	AAC	CAC	AAC	CAC	AAC
50	0.7	1.8	7	9	1.3	34	88	789	59	65
100	1.1	3.9	12	18	3.2	82	100	1418	97	107
200	2.0	8.6	21	34	7.7	197	100	2549	191	211
250	2.3	11.0	26	42	10.2	262	100	3079	230	254
300	2.7	13.5	30	50	12.9	331	100	3592	269	297

Source: Title 327 IAC 2-1-6.
Units**B**Hardness**B**milligrams per liter
Total Recoverable metals**B**micrograms per liter

Water hardness may be affected by many factors such as soil types and thickness, sewage or industrial wastes, rainfall and stream base flow patterns. During lower flows most stream water is probably ground water that has filtered through layers of soil, thereby assimilating more minerals, resulting in higher hardness values. “Normal” flow is usually a combination of surface run-off and ground water that may somewhat buffer the higher hardness of ground water. During extremely high flows, there is significantly more surface run-off than ground water. Therefore, hardness values tend to be lower than at "normal" flow.

Figure 4 graphically illustrates the flow-hardness patterns in the Upper Wabash River Basin during the 1998 sampling events. Only those stations with relevant USGS stream flow gages are included in this grouping.

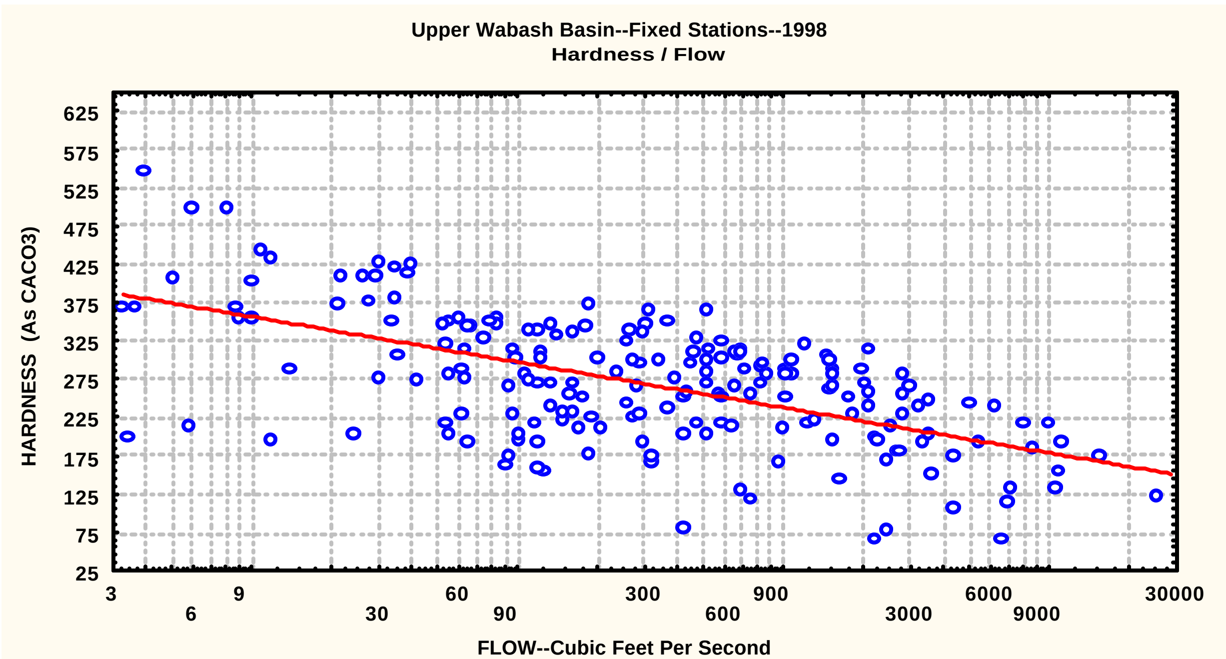

Figure 4 Upper Wabash River Basin Hardness vs Stream Flow

During the 1998 fixed station sampling of the Upper Wabash River Basin, a total of 372 samples were collected for analysis of nine parameters for Total Recoverable Metals. This number includes lead and mercury, however Total Iron was not counted due to lack of a criterion for this metal. Therefore, 2976 discrete analytical tests were performed on these samples. From the total analyses, 100 stream standard violations were noted based on the Chronic Aquatic Criteria tables referenced earlier. Of those 100, only four (4) violated the Acute Aquatic Criteria (Table 1).

On July 21 and 22, 1998 severe thunderstorms tracked across north central Indiana. Six to eight inches of rain were recorded in Wabash County in less than 24 hours. At Bluffton in Wells County, six inches of rain fell in less than five hours. These rainfall events brought streams to flood stage in many areas. USGS stream flow gaging stations recorded flows from 8 to 25 times the historical average flows for those days. Similar conditions were also present in early May. Flows were not as high as July flows, but were still 5 to 16 times the normal flow for those dates. The result of heavy surface run-off produced high stream flows and corresponding lowered hardness in both events (Figure 3). This combination of increased flow and lowered hardness resulted in violations of total copper, cadmium, and zinc water quality standards (Table 2).

NUTRIENTS

Spatial distribution trends from upstream to downstream on the sampled water bodies were examined for this report. Four nutrient parameters, Phosphorus, Total Kjeldahl Nitrogen (TKN), Total Organic Carbon (TOC) and Nitrate+Nitrite were selected as parameters of interest. Data from the 1998 Fixed Station Wabash River sites were combined into one set and descriptive statistics were derived from this set to provide values for evaluation. Lower Wabash River sites were included in this review to give a picture of the entire river. These statistics are presented in Table 4.

In addition, all data from 1991 through 1998 for these same sites were combined into one set and descriptive statistics were calculated to provide median values for comparison. That information is presented in Table 5. Box and whisker plots were created from the data sets of each sampling location on the main stem Wabash River and its major tributaries including the Mississinewa, Salamonie and Tippecanoe Rivers. The box and whisker plots presented in Appendices C - H not only display the range of values at each site, but also demonstrate upstream/downstream trends if present. The median values from the main stem Wabash River data set (Table 5) were used as standard values for evaluation of nutrients data. The median values for nutrients were identified as follows: Total Phosphorus 0.2 mg/L, TKN 1.1 mg/L, Total Organic Carbon 5.5 mg/L, and Nitrate+Nitrite 3.5 mg/L.

The box plots for Phosphorus (Appendix D-1), in the Salamonie River show site S-71 with a median concentration above 0.2 mg/L. All sites on this river were above 0.1 mg/L which is the USEPA recommended level for preventing nuisance plant growth in streams (USEPA 1999, USGS 1999). The Mississinewa River (Appendix C-1) did not have any values above the median of 0.2 mg/L, though all except the site below the reservoir MS-1 were above 0.1 mg/L. The Tippecanoe River (Appendix E-2) did not have any sites with a median value above 0.2 mg/L and most sites were below 0.1 mg/L. The Wildcat Creek (Appendix F-2) had numerous sites with medians above 0.2 mg/L.

None of the additional tributaries were above 0.2 mg/L but only two sites had medians below 0.1 mg/L. Those were PIP-5 and ELL-7 (Appendix H-2). The Wabash River main stem had several sites with medians well above 0.2 mg/L. These occurred in the upper reaches at sites WB-452, WB-420, WB-409, and WB-402 (Appendix G-3). Several sites further downstream were just at or slightly over the 0.2 mg/L level.

Total Kjeldahl Nitrogen median values in the Salamonie River were all below 1.1 mg/L (Appendix D-2). The same held true for the Mississinewa (Appendix C-2), Tippecanoe Rivers (Appendix E-1) and the Wildcat Creek (page F-1). None of the additional tributaries sampled were above 1.1 mg/L (Appendix H-1). The Wabash River main stem had four sites in the upstream reaches which produced medians above 1.1 mg/L (Appendix G-2). These were the same sites above the Peru area that had higher median values for phosphorus.

Total Organic Carbon median values in the Salamonie River were all above the 5.5 mg/L median value of the main stem Wabash River (Appendix D-2). The Mississinewa (Appendix C-2) and Wildcat Creek (Appendix F-2) median values were all below this level. The other tributaries sampled exhibited medians below 5.5 mg/L except for the Eel River at ELL-66 (Appendix H-2). The Tippecanoe River values were mostly above the 5.5 mg/L value (Appendix E-2). The main stem Wabash River showed higher median levels in the upper reach at sites WB-452, WB-420, WB-409 and WB-402 (Appendix G-3).

Nitrate+Nitrite median values in the Mississinewa (Appendix C-1), Salamonie (Appendix D-1) and Tippecanoe Rivers (Appendix E-1) were all found to be below 3.5 mg/L. The Wabash River tributary locations were also below this level except for Deer Creek at DC-5 that had a median of >7.0 mg/L (Appendix H-1). The Wildcat Creek (Appendix F-1) and lower stretches of the Wabash River generally demonstrated levels higher than the level of concern (Appendix G-1).

Two dimensional multiple-line plots displaying chemical parameter data in a seasonal manner by month are shown in Appendices C, D, F, and G. Phosphorus, Total Organic Carbon, ammonia, nitrate+nitrite, and Total Kjeldahl Nitrogen concentrations are displayed compared to stream flow. Stream flow values are from USGS gages located at or near the specific sites graphed. Not many direct correlation's can be made between increases in the parameter concentrations with increases in stream flow. It must be kept in mind when viewing these graphs that the levels of stream flow at each point could be falling or rising which would influence the parameter concentrations. Some increases in parameter concentrations seem to be consistent with respect to certain seasons. For example phosphorus at several sites is seen to rise in concentration in the summer months.

Histograms have also been included in the Appendices that show ranges of values of chemical parameters sampled as percentages of observations. This data set for the 1998 Fixed Station sampling includes all sites on the Wabash River including those in the Lower Wabash basin. According to these graphs almost 60 percent of the observations for phosphorus fell into the range above 0.2 mg/L.

QUALITY ASSURANCE/QUALITY CONTROL

Data Quality

IDEM chemists from the Toxicology and Chemistry Section, Assessment Branch, OWQ reviewed lab data reports from samples for the 1998 Fixed Station Water Quality Monitoring Program Samples for compliance to the Surface Water QAPP requirements for Quality Assurance / Quality Control (QA/QC).

Precision

The in-lab quality assurance for data in this report for analytical precision was based on laboratory duplicates, matrix spike duplicates, and Relative Percent Difference (RPD). Most RPDs for almost all the parameters were within control limits (+/- 20%), but some high RPDs were noted with some data sets for total iron and total mercury. Affected results were flagged as estimated.

Accuracy
The in-lab analytical accuracy was based on matrix spikes, matrix spike duplicates, quality control samples, and on-going performance recovery samples. Laboratory QC samples were within control limits for the parameter. However, some sample sets had MS/MSD recoveries outside of acceptable limits for total iron and total mercury. Affected results were flagged as estimated.

Holding Times
Laboratory holding times for all the parameters were within acceptable limits per Table 2 in 40 CFR part 136.

Blanks
Significant results, greater than the MRL, for a parameter indicates contamination from the field sampling process (field blanks) or laboratory sample preparation (field blanks or lab blanks). Low level contamination of total zinc and total organic carbon (TOC) were noted for some data sets. Affected results were flagged as estimated.

Of the 10,600 results gathered for this project, only 1% (110) were qualified as estimated. None were rejected. As per the Surface Water QAPP, the data was qualified at Data Quality Assessment Level 3 and acceptable for use in IDEM decision making processes.

TEMPORAL TRENDS IN WATER QUALITY PARAMETERS
Stream chemistry is highly dynamic and can change rapidly over time as a result of rainfall and other characteristics of the watershed. To further complicate this dynamic nature, seasonality also can affect the chemistry of the water. Consequently, many types of linear regression will not succeed in determining if a given parameter is actually changing over time due to outliers and seasonal fluctuations.

One method for determining if a given parameter is changing over time is known as the Seasonal Kendall test. This test only compares data that were taken during the same *season*. Season is defined by the user as either months or quarterly seasons. In other words, the test only compares like months (January data to January data) or like seasons (Fall data to Fall data) as defined by the user. Thus, the effects of seasonality are eliminated from the test. To reduce the effects of outliers, the test only measures if change occurs between the seasons, not the magnitude of the change. This test is good for a broad-based approach to water quality analysis for a large number of sampling stations, although other tests are better suited to determine if a specific management program or watershed activity is affecting a given sampling station over a period of time (Figure 2).

Table 4 Upper Wabash River Basin Fixed Stations 1998 Metals Analyses and Total Recoverable Standards Violations (CAC)

Parameter	Total # Tests	Total Violations	% Violations
Arsenic	372	0	0
Cadmium	372	5(1)	1.6
Chrome, Tot.	372	0	0
Copper	372	5(2)	1.9
Lead	372	45*	12*
Mercury	372	44*	11.8*
Nickel	372	0	0
Zinc	372	1(1)	0.5
Totals	**2976**	**100(4)**	**3.5**

*See discussion under Lead and Mercury Analysis on pages10-11 of this report.

Table 5 Upper Wabash Fixed Stations Stream Standard Violations Total Copper, Zinc and Cadmium.

Station	Date	Total Cu (μg/L)	Zn (μg/L)	Cd (μg/L)	Hardness (mg/L)	Flow (cfs)
BMC-1	5/13/98	--	--	14.0**	281	No gage
MS-1	5/11/98	--	--	2.7	204	3490
MS-99	7/22/98	8.8	77	1.0	67	2190
PIP-5	7/22/98	11.0	--	--	67	No gage
S-25	7/23/98	9.7	--	--	65	6670
S-71	7/22/98	22.0**	--	--	82	420
WB-347	5/11/98	--	390**	--	216	10000
WB-347	7/22/98	27.0**	--	--	120	25400
WB-402	7/23/98	11.0	--	1.5	91	685
WB-452	7/22/98	12.0	--	2.4	77	2430
WC-66	5/12/98	--	--	3.3	228	No gage

** Indicates violation of AAC as well as CAC

The WQHYDRO program was used to conduct the Seasonal Kendall test. Data for this test were downloaded from the EPA's STORET database in an ASCII format, edited into a usable form in the DOS editor, augmented with data not currently in STORET, and loaded into WQHYDRO for analysis.

The data was divided into four separate decades for analysis. These were 1959 to 1968, 1969 to 1978, 1979 to 1988, and 1989 to 1998. If an observation was reported below the detection limit, the observation was assigned a value of one half the detection limit. Some of the parameters that have been collected by the agency were not evaluated in this manner because too many observations were below the detection limit or the given parameter was not evaluated often enough to have a meaningful test. For this study, it was decided that a minimum of seven years of observations within the decade was required in order to conduct the Seasonal Kendall analysis. The test was also conducted on sites which are currently being sampled.
The Seasonal Kendall test produces two important statistics. The first is the significance of the test. The significance indicates if the test statistically found a change in the parameter over time. In general, statisticians prefer to see a significance of 95% or greater to accept that there truly is a change. However, in some cases a significance as low as 80% will be accepted. The second statistic is the slope (rate of change) that the parameter exhibits over the time period. This value can be either positive (increasing) or negative (decreasing). This slope is reported as low as +/- 0.00001, and slopes smaller than these are practically or truly equal to zero.

This document uses these two statistics to create a classification for each test. Table 6 lists the criteria and the classifications that are possible for a given test.

Table 6 Classifications for Seasonal Kendall Results

Classification	Abbreviation	Significance of Test	Reported Slope
Statistically Increasing	SI	95% or Greater	Positive
Potentially Increasing	PI	80% to 94%	Positive
No Change	NC	Less than 80%	Positive or Negative
No Change	NC	80% or Greater	0.00000
Potentially Decreasing	PD	80% to 94%	Negative
Statistically Decreasing	SD	95% or Greater	Negative

Note that it is possible for a test to be highly significant (99%), but have a slope so small (<0.00001) that there is practically no change in the parameter over time. For this reason, an additional classification of “No Change” was included in the course of the analysis.

Some of the more notable trends are listed in Tables 7 - 10. Those trend lines that were either significantly increasing or significantly decreasing are highlighted in the Tables. The metal and nutrient parameter values demonstrated a high variability with respect to trends that were specific to individual sampling sites. Chloride and Hardness values were shown to be statistically increasing at Eel, Tippecanoe and Wabash River sites in the 1959-1968 (Table 7). Chlorides continued to increase at the Salamonie and Wabash sites in 1969 to 1978 (Table 8). In the 1989 to 1998 (Table 10), pH is shown to be increasing at most of the sites while hardness and total solids are shown to be decreasing. Selected graphs of these trends are shown in the Appendix I. It should be kept in mind when interpreting these graphs that an increasing slope does not necessarily mean that the change is significant or great enough for concern. That decision must be based on the Water Quality Standards or selected levels of concern.

Table 7 Upper Wabash River Basin Seasonal Kendall Analysis Summary 1959 to 1968

Station	Alkalinity	BOD	Chloride	D.O.	Hardness	Suspended Solids
ELL-7	NC	PI	SI	NC	SI	
S-0	NC	NC	SI	SI	NC	
TR-9	NC	SI	SI	SI	SI	NC
WB-409	NC	NC	SI	NC	SI	
WB-370	NC	NC	SI	NC	SI	SD

Table 8 Upper Wabash River Basin Seasonal Kendall Analysis Summary 1969 to 1978

Station	BOD	Cl	D.O.	Nitrate	PH	Total Phosphorus	Suspended Solids	Sulfate
MS-36			NC		PD			
MS-28	SI	PI	NC		PD	SD	NC	
MS-1					SD			
S-25		SI	SD		SD			
S-0	NC	SI	SD		PD			SI
WB-420	SI	SI	NC		PD		PI	
WB-409	NC	SI	SD		NC			SI
WB-370	PD	SI	PI	PD	PD	SD	NC	SI
WC-66			PI		SD			

Table 9 Upper Wabash River Basin Seasonal Kendall Analysis Summary 1979 to 1988

Station	Alk	NH_3	BOD	Cd	Cl^-	Cr	COD	Cu	CN	DO	Hard	Fe	Pb	Hg	Ni	NO_3	pH	Total-P	TDS	TSS	Sulf	TKN	Zn
ELL-7		NC	NC		NC		NC			NC				NC		NC	NC	NC		NC	NC		
MS-99	SI	NC	NC		SI	NC	NC	NC	NC	NC	PI		NC	NC	NC	PD	NC	SI		NC	PI		NC
MS-36		NC	NC		NC		PD			PI						NC	SI	SD		NC	NC		
MS-28		NC	NC		NC		PD			PI	NC					NC	SI	NC		PD	NC		
MS-1		NC	NC		NC					PD						NC	NC	NC		NC	SI		
S-0		NC	NC		SI					PD						NC	SI	NC		PD	NC		
TR-9		NC	NC		NC					NC						PI	SI	SI		SI	SD		
WB-452	NC	NC	PI		PI	NC	PD	SD	NC	NC	NC	SI	NC	NC	NC	PI	NC	SI		NC	SI	SI	NC
WB-420		NC	NC		NC		PI			NC						NC	PI	SI		NC	NC		
WB-409		NC	NC							NC						NC	NC	NC		PD	NC		
WB-402		NC	NC		NC					PI						NC	PI	SI		NC	NC		
WB-370		NC	NC		NC					PD						NC	NC	SI		PI	NC		
WB-347		NC	NC		PI		NC			NC				NC		NC	PI	SI		NC	NC	NC	
WC-66	PI	NC	NC	NC	NC	NC	PI	NC	NC	NC	NC	SI	NC	NC	NC	SD	NC	SI	NC	NC	NC	SI	NC

Table 10 Upper Wabash River Basin Seasonal Kendall Analysis Summary 1989 to 1998

Station	Alk	NH_3	BOD	Cd	Cr	COD	Cu	CN	DO	E. coli	Hard	Fe	Pb	Hg	Ni	NO_3	pH	Total-P	TDS	TSS	TS	TKN	Zn
ELL-41	NC	NC	NC		NC	SD		NC	NC	PI	SD					SD	SI	NC		NC	SD		
ELL-7	NC	NC	NC			SD			NC	PI	PD					PD	SI	NC		SD	SD		
MS-99	SD	NC	NC		NC	NC		NC	NC	PD	SD			NC	NC	PD	SI	NC		NC	SD		
MS-36	SD	NC	NC	NC		NC	NC		NC	PD	SD		NC	NC	NC	PD	SI	NC		NC	NC	NC	
MS-28	SD	NC	NC			NC			NC	NC	PD					SD	SI	PI		NC	NC		
MS-1	SD	NC	NC						NC	PI	SD					NC	SI	NC		PD	SD	NC	
S-71	PI	NC	NC		NC	NC		NC	NC	NC	SI			NC		PD	SI	SI		PD	SI		
S-25	NC	NC	SI		NC	NC			NC	NC	NC					SD	SI	NC		SD	NC		
S-0	NC	NC	PI			NC			NC	NC	SD					SD	SI	SI		PD	SD		
TR-107	NC	NC	NC						NC	NC	SD			NC		NC	SI	NC		PI	SD		
TR-9	NC	NC	NC		NC	SD			NC	PD	PD					SD	NC	SD		SD	SD		
WB-452	SI	NC	NC	NC	NC	NC	SD	NC	NC	NC	NC	SD	NC	NC	SI	SD	SI	NC		SD	NC		SD
WB-420	NC	NC	NC			NC	SD		NC	NC	PD					SD	SI	NC		NC	NC		
WB-409	NC	NC	SI			PD	SD		NC	NC	PD					PD	SI	NC		NC	SD		
WB-402	NC	NC	PI			NC	SD	NC	NC	NC	PD					SD	SI	PI		NC	NC		
WB-370	PD	NC	NC				SD		NC	NC	SD					NC	SI	NC		NC	SD		
WB-347	NC	NC	NC			NC			NC	NC	PD			NC		NC	PI	NC		PD	NC		
WB-316	PD	NC	NC		NC	NC	NC	NC	NC	NC	SD	NC	NC	NC	NC	PD	SI	NC		NC	SD	PD	NC
WC-66	SD	NC	NC			NC		NC	PD	SI	SD			NC		SD	PI	NC	SD	NC	SD		
WC-60	PD	NC	NC	NC	NC	NC		NC	NC	NC	SD			NC		PD	PI	SI		NC	PD		
WC-3	SD	NC	NC		NC	NC			NC		SD			NC		NC	NC	PI		NC	NC		
WCS-34	NC	NC	NC	NC	NC	NC		NC	PD		PD		NC	NC		NC	PI	NC		NC	NC		

SUMMARY AND CONCLUSIONS

In accordance with IDEM's Surface Water Monitoring Strategy, the Upper Wabash River Basin was the focus of water quality assessment in 1998. This report presents water quality monitoring data and trends that were the results of water quality sampling of the Fixed Station Monitoring Program of 1998. The data presented here are from the upper Wabash Basin as defined by the OWM Surface Water Quality Monitoring Strategy 1996-2000 (IDEM 1998a). The following conclusions can be made:

$ In the Upper Wabash River Basin a total of 372 Fixed Station water samples were collected for analysis of nine Total Recoverable Metals :arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc. Out of 2,976 discrete analytical tests, 100 exceeded values for stream standards based on the Chronic Aquatic Criteria. Only four sites also exceeded the Acute Aquatic Criteria. Most of these 100 values were for Lead and Mercury.

$ With respect to the nutrient parameters that were sampled and examined, the upper reaches of the main stem of the Wabash River had several sites that were higher than the median values of nutrient parameters derived from the data set of the main stem as a whole. The median values of Phosphorus, Total Kjeldahl Nitrogen and Total Organic Carbon were 0.2 mg/L, 3.5 mg/L and 5.5mg/l, respectively.

$ The Wildcat Creek had numerous sites that were higher than 0.2 mg/L for phosphorus in the upper reaches. Out of 44 tests for Total Phosphorus on 5 sites, 21 had values over 0.2 mg/L.

$ The Salamonie River had higher than (5.5mg/L) median values for Total Organic Carbon. Out of 47 tests on 5 sites, 34 were over 5.5 mg/L.

$ The lower stretches of the Wabash River and Wildcat Creek demonstrated higher levels of Nitrate + Nitrite than the other tributaries. These levels were greater than 3.5 mg/L. Out of 44 tests for nitrate+nitrite on five sites, 26 values were greater than 3.5 mg/L.

$ For temporal or seasonal trend analysis, Seasonal Kendall tests using the WQHYDRO statistical software were performed on water quality monitoring data from the Upper Wabash River Basin Fixed Station sites. Historical water quality data from 1959 to 1998 were examined. The metals and nutrient parameter values showed a high variability with respect to trends specific to individual sampling sites. Chloride and Hardness values were shown to be, in general, statistically increasing on the Salamonie and Wabash River sites during the period from 1959 to 1978. During the period from 1989 to 1998, pH was shown to be increasing at most of the sites, while hardness and total solids are shown to be decreasing.

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Appendix A Site Locations

(New sites are printed in italics)

Hydrologic Unit Code/ Station #		**Stream Name and Location**	**Latitude**			**Longitude**		
05120101		**Wabash River and tributaries--State Line to Logansport**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
050	WB-452	*Wabash River at US 27, north of Geneva (Linn Grove gaging station)	40	36	59	84	57	14
070	WB-420	Wabash River at SR 3, at Markle	40	49	26	85	20	22
090	WB-409	*Wabash River at Old SR 9, Huntington (Gage at power plant)	40	51	29	85	30	27
110	***LR-7***	**Little River, CR 200 E, nr Mardenis (Gage just upstream)*	40	53	55	85	24	48
130	WB-402	Wabash River at SR 105, near Andrews	40	52	08	85	36	06
150	WB-370	**Wabash River at Peru, (Business route 31 west edge of town)	40	44	32	86	05	48
170	***PIP-5***	*Pipe Creek, Cass CR 925 E, nr Onward*	40	43	18	86	11	54
05120102		**Salamonie River and tributaries**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
010	S-71	**Salamonie River at Portland, (county road bridge 3.2 miles west)	40	25	40	85	02	19
020	***S-52***	*Salamonie River at SR 18, west of Montpelier, at Matamora*	40	33	17	85	15	42
040	S-25	Salamonie River at SR 124, south of Lancaster	40	44	30	85	30	32
040	S-0	*Salamonie River at Division Road, Lagro (Dora gaging station)	40	49	47	85	43	07
05120103		**Mississinewa River and Tributaries**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
020	MS-99	**Mississinewa River near Ridgeville, CR bridge, 2 miles east of town	40	16	48	84	59	43
030	***MS-68***	*Mississinewa River at Center Road, just DS of Eaton*	40	20	38	85	23	18

Hydrologic Unit Code/ Station #		**Stream Name and Location**	**Latitude**			**Longitude**		
060	MS-36	**Mississinewa River, Highland Avenue bridge, Marion	40	34	34	85	39	34
060	MS-28	Mississinewa River at Jalapa	40	37	32	85	43	56
060	MS-1	*Missinewa River at SR 124 near Peru (Peoria gaging station)	40	45	14	86	01	23
05120104		**Eel River and tributaries**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
040	*ELL-66*	*Eel River at South Whitley*	41	04	57	85	37	39
050	ELL-41	*Eel River at SR 15, Roann (North Manchester gaging station)	40	54	49	85	56	39
070	ELL-7	**Eel River, Adamsboro Road (CR 125N) 5.5 miles NE of Logansport	40	46	58	86	15	51
05120105		**Wabash River and tributaries--Logansport to Lafayette**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
010	WB-347	Wabash River at CR 675 near Georgetown	40	44	20	86	30	10
050	*DC-5*	***Deer Creek, CR 300N, near Delphi*	40	35	25	86	37	17
070	WB-316	Wabash River at SR 225 near Battleground	40	29	44	86	49	24
05120106		**Tippecanoe River and tributaries**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**
010	*TR-164*	***Tippecanoe River, SR 13, at North Webster*	41	18	58	85	41	32
030	*TR-139*	*Tippecanoe River, CR 700W, south of Atwood*	41	14	39	85	58	40
050	TR-107	Tippecanoe River at US 31, near Rochester	41	05	39	86	14	25
080	*TR-56*	*Tippecanoe River at SR 119, south of Winamac*	41	00	24	86	36	10
110	*BMC-1*	*Big Monon Ditch at SR 16, north of Monticello*	40	52	09	86	46	44
150	TR-9	**Tippecanoe River, SR 18, Springboro, 5 miles west of Delphi	40	35	38	86	46	14
05120107		**Wildcat Creek and Tributaries**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**

020	WC-66	Wildcat Creek at US 31, Kokomo	40	29	10	86	06	27
020	WC-60	*Wildcat Creek at CR 300W near Kokomo (Gage at Kokomo STP)	40	28	25	86	11	03
020	WC-24	Wildcat Creek at US 421 and SR 39	40	27	53	86	38	12
020	*WC-32*	*Wildcat Creek at SR 75 near Cutler*	40	28	54	86	31	48
030	*WCM-7*	*Middle Fork, Wildcat Creek, at SR 26, Edna Mills*	40	25	02	86	39	49
040	WCS-34	South Fork, Wildcat Creek at SR 38-39, at Frankfort (Quarterly)	40	18	59	86	32	48
050	WC-3	*Wildcat Creek at SR 25, north of Lafayette (CR 2A east, gaging station) (Quarterly)	40	27	13	86	51	05

***Indicates USGS gaging station near site**
**** Indicates USGS gaging station at site**

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Appendix B Upper Wabash Fixed Station Violations 1998

(Note: See discussion under Lead and Mercury Analysis on pages10-11 of this report.)

Station	Date	Parameter	Concentration - mm/L
BMC-1	5/13/98	Cadmium	14
BMC-1	8/17/98	Lead	18
BMC-1	5/13/98	Mercury	0.1
BMC-1	9/8/98	Mercury	0.1
DC-5	8/17/98	Lead	19
ELL-7	8/18/98	Lead	16
ELL-7	8/18/98	Mercury	0.2
ELL-41	6/15/98	Cyanide	0.022
ELL-41	2/25/98	Lead	12
ELL-41	8/27/98	Lead	14
ELL-41	9/24/98	Mercury	0.2
ELL-66	4/20/98	Mercury	0.2
ELL-66	9/24/98	Mercury	0.2
LR-7	9/24/98	Mercury	0.10
MS-1	8/18/98	Lead	11
MS-1	9/8/98	Cyanide	0.006
MS-1	8/18/98	Mercury	0.1
MS-1	5/11/98	Cadmium	2.70
MS-28	2/24/98	Lead	12
MS-28	8/27/98	Lead	16
MS-36	6/18/98	Cyanide	0.007
MS-36	4/20/98	Mercury	0.2
MS-36	9/23/98	Mercury	0.1
MS-68	8/19/98	Mercury	0.2
MS-68	9/14/98	Mercury	0.1
MS-99	9/15/98	Lead	18
MS-99	8/20/98	Mercury	0.1
MS-99	7/22/98	Cadmium	1.00
MS-99	7/22/98	Copper	8.8
MS-99	5/20/98	Cyanide	0.006

Station	Date	Parameter	Concentration - mm/L
MS-99	7/22/98	Zinc	77
PIP-5	7/22/98	Copper	11
PIP-5	8/18/98	Lead	18
PIP-5	9/8/98	Lead	12
S-0	2/25/98	Lead	15
S-0	4/20/98	Mercury	0.2
S-0	9/24/98	Mercury	0.1
S-25	7/23/98	Copper	9.7
S-25	6/17/98	Cyanide	0.007
S-25	2/25/98	Lead	14
S-52	3/23/98	Mercury	0.1
S-52	5/19/98	Mercury	0.2
S-52	8/19/98	Mercury	0.2
S-71	7/22/98	Copper	22
S-71	5/20/98	Cyanide	0.011
S-71	8/20/98	Cyanide	0.007
S-71	1/27/98	Dissolved Solids	769
S-71	9/15/98	Dissolved Solids	1003
S-71	9/15/98	Sulfate	255
S-71	10/20/98	Dissolved Solids	1060
S-71	11/09/98	Dissolved Solids	911
TR-9	8/17/98	Mercury	0.2
TR-9	12/8/98	Mercury	0.1
TR-9	8/17/98	Lead	17
TR-56	5/13/98	Mercury	0.2
TR-56	8/17/98	Mercury	0.1
TR-56	8/17/98	Lead	17
TR-139	8/27/98	Lead	12
TR-164	8/27/98	Lead	11

Station	Date	Parameter	Concentration - mm/L
TR-164	5/21/98	Mercury	0.2
TR-164	6/15/98	Mercury	0.2
WB-316	3/12/98	Lead	9
WB-316	8/13/98	Lead	13
WB-316	9/8/98	Lead	11
WB-316	4/14/98	Mercury	0.2
WB-316	11/13/98	Mercury	0.2
WB-347	7/22/98	Lead	12
WB-347	8/17/98	Lead	14
WB-347	9/8/98	Lead	11
WB-347	4/14/98	Mercury	0.2
WB-347	8/17/98	Mercury	0.2
WB-347	9/8/98	Mercury	0.1
WB-347	7/22/98	Copper	27
WB-347	5/11/98	Zinc	390
WB-370	7/22/98	Lead	6.6
WB-370	8/18/98	Lead	11
WB-370	9/8/98	Lead	9.6
WB-370	8/18/98	Mercury	0.1
WB-402	5/21/98	Cyanide	0.006
WB-402	6/16/98	Cyanide	0.076
WB-402	8/27/98	Cyanide	0.008
WB-402	2/25/98	Lead	12
WB-402	8/27/98	Lead	11
WB-402	4/21/98	Mercury	0.2
WB-402	8/27/98	Mercury	0.2
WB-402	9/24/98	Mercury	0.1
WB-402	7/23/98	Cadmium	1.50
WB-402	7/23/98	Copper	11
WB-409	12/9/98	Ammonia	0.60

Station	Date	Parameter	Concentration - mm/L
WB-409	5/21/98	Cyanide	0.013
WB-409	6/16/98	Cyanide	0.076
WB-409	8/27/98	Cyanide	0.007
WB-409	9/24/98	Cyanide	0.006
WB-409	2/25/98	Lead	15
WB-409	8/27/98	Lead	9.9
WB-409	9/24/98	Lead	9.2
WB-420	8/26/98	Ammonia	0.6
WB-420	8/36/98	Lead	17
WB-420	9/14/98	Lead	14
WB-420	4/21/98	Mercury	0.1
WB-420	6/16/98	Cyanide	0.088
WB-452	12/10/98	Ammonia	0.7
WB-452	6/17/98	Cyanide	0.032
WB-452	9/14/98	Lead	17
WB-452	12/10/98	Mercury	0.1
WB-452	7/22/98	Cadmium	2.40
WB-452	7/22/98	Copper	12
WB-452	10/19/98	Dissolved Solids	816
WC-3	8/13/98	Lead	16
WC-3	4/14/98	Mercury	0.1
WC-3	8/13/98	Mercury	0.2
WC-24	8/17/98	Lead	20
WC-24	5/13/98	Mercury	0.1
WC-24	8/17/98	Mercury	0.1
WC-60	1/20/98	Ammonia	1.8
WC-60	2/12/98	Ammonia	2.0
WC-60	1/20/98	Cyanide	0.006
WC-60	2/12/98	Cyanide	0.013

Station	Date	Parameter	Concentration - mm/L
WC-60	4/15/98	Cyanide	0.006
WC-60	5/12/98	Cyanide	0.009
WC-60	8/18/98	Lead	17
WC-60	9/8/98	Lead	12
WC-60	10/7/98	Lead	7
WC-60	9/8/98	Mercury	0.1
WC-66	5/12/98	Cyanide	0.006
WC-66	6/10/98	Cyanide	0.006
WC-66	2/12/98	Lead	12
WC-66	3/17/98	Lead	12
WC-66	8/18/98	Lead	14
WC-66	9/8/98	Lead	8.8
WC-66	4/15/98	Mercury	0.2
WC-66	7/22/98	Mercury	0.1
WC-66	8/18/98	Mercury	0.1
WC-66	5/12/98	Cadmium	3.30
WCM-7	8/17/98	Lead	19
WCS-34	5/13/98	Cyanide	0.007
WCS-34	8/17/98	Cyanide	0.011
WCS-34	9/9/98	Cyanide	0.024
WCS-34	10/05/98	Cyanide	0.007
WCS-34	11/12/98	Cyanide	0.016
WCS-34	8/17/98	Lead	19
WCS-34	4/14/98	Mercury	0.1
WCS-34	8/17/98	Mercury	0.1

Parameters Examined

Metals (violations found)
Sulfate (violations found)
Ammonia (violations found)
Chlorides (violations not found)
Nitrates (violations not found)
Cyanide (violations found)
Dissolved Solids (violations found)
Dissolved Oxygen (violations not found)
pH (violations not found)

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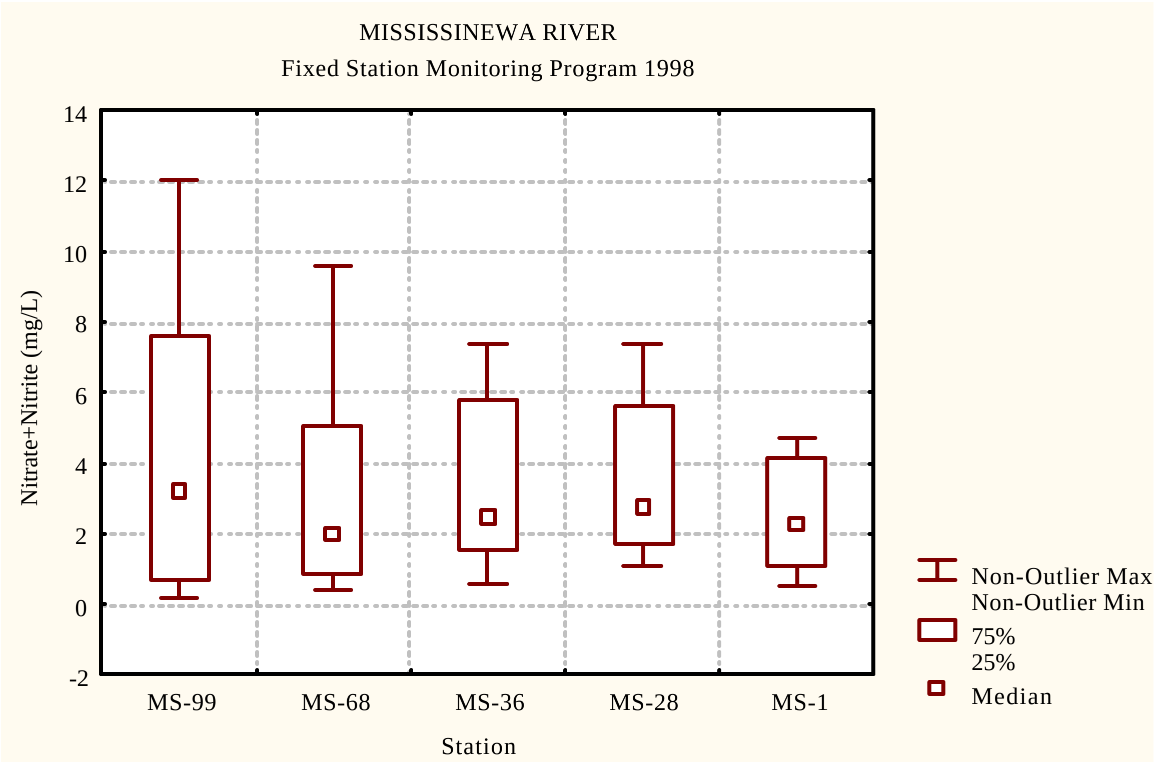
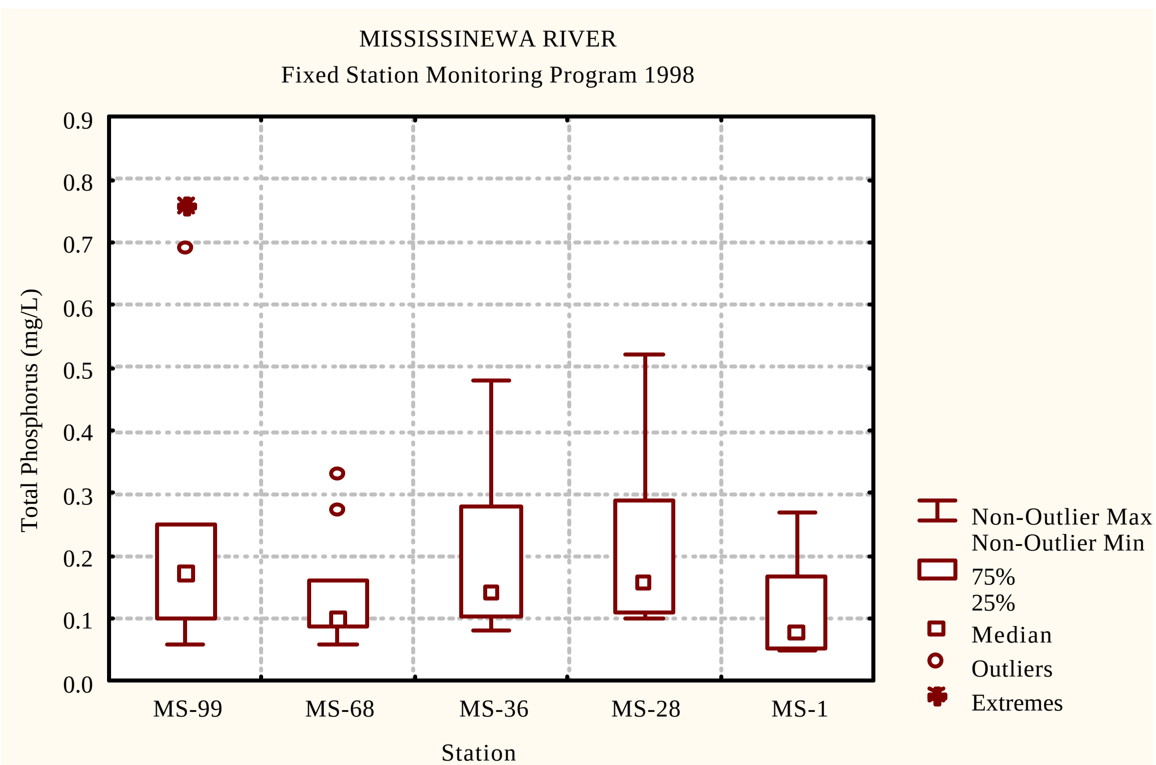
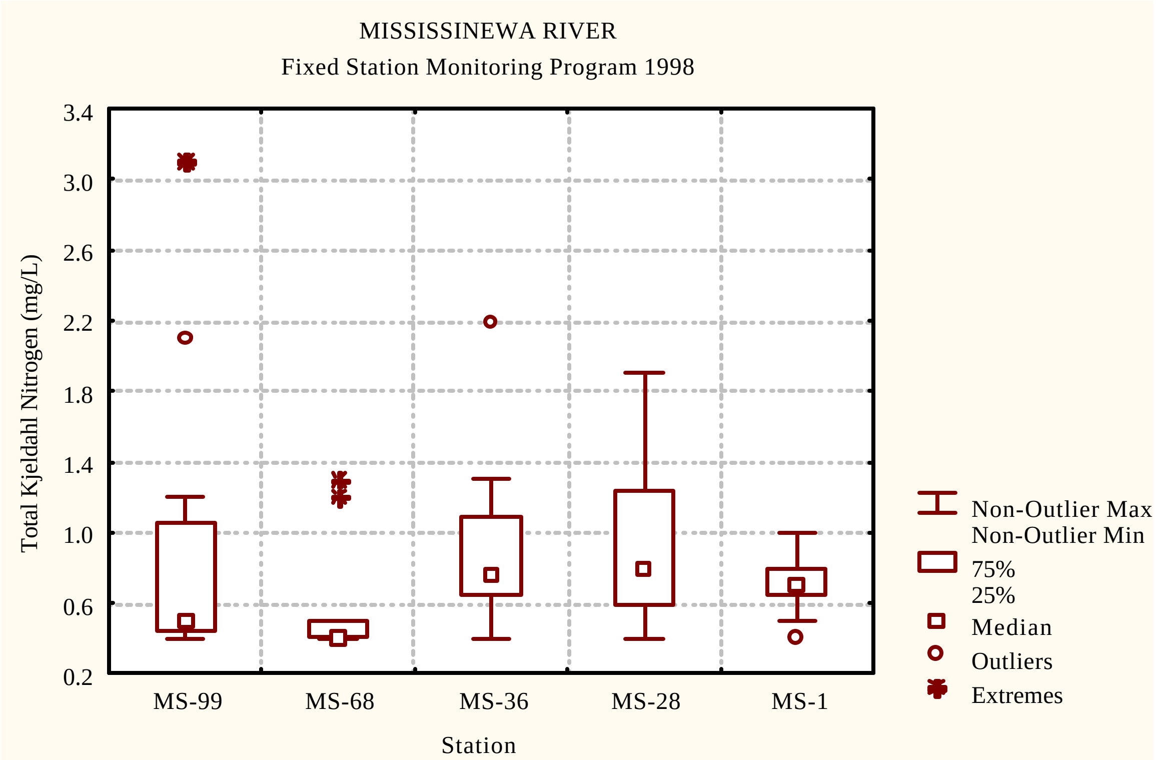
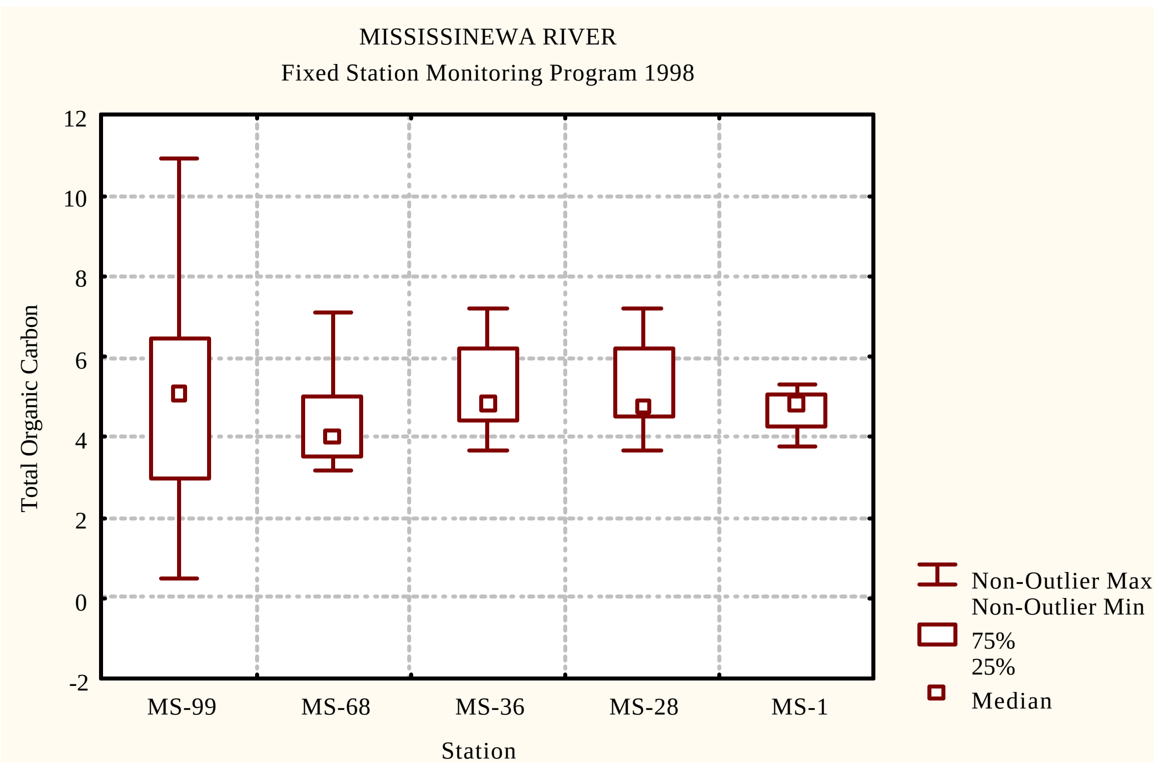
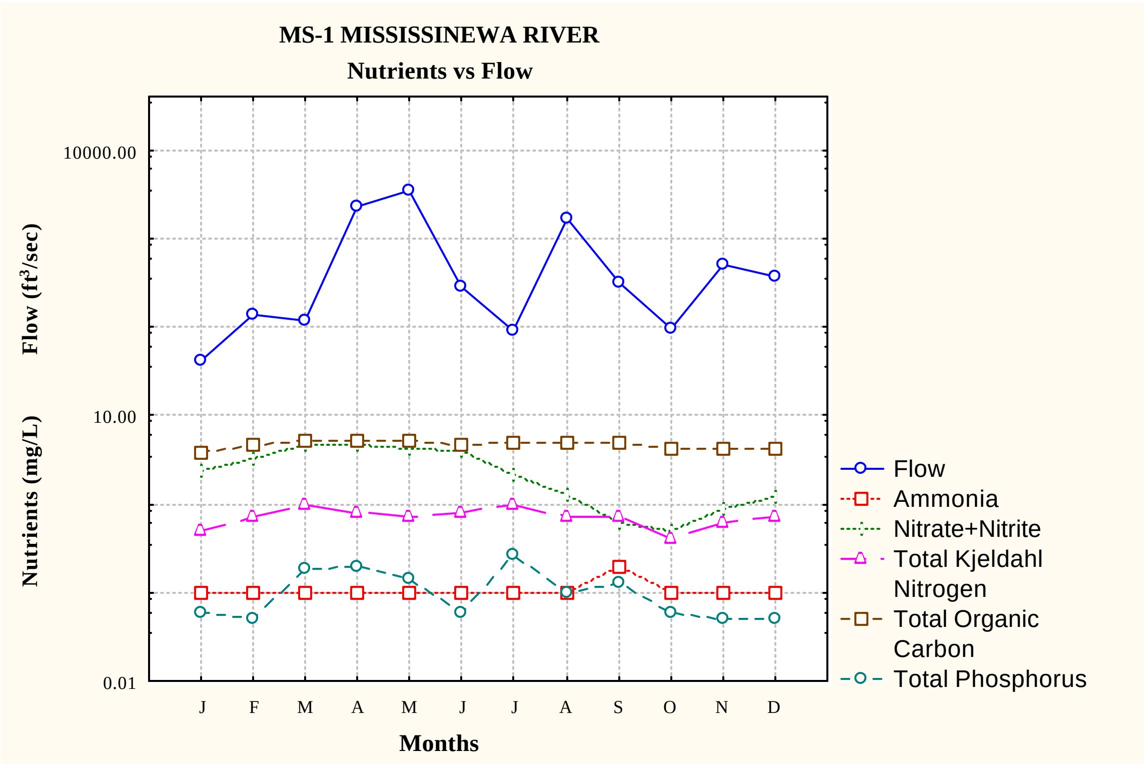
Appendix C Selected Water Quality Parameters in the Mississinewa River Basin

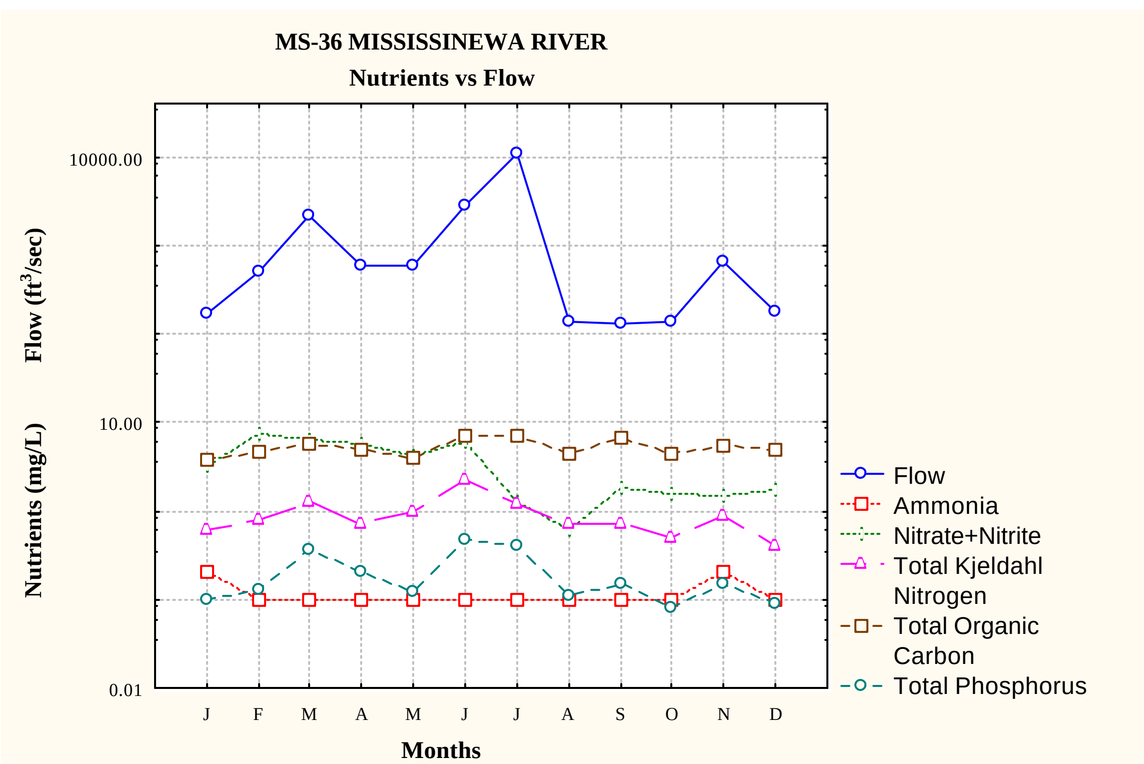


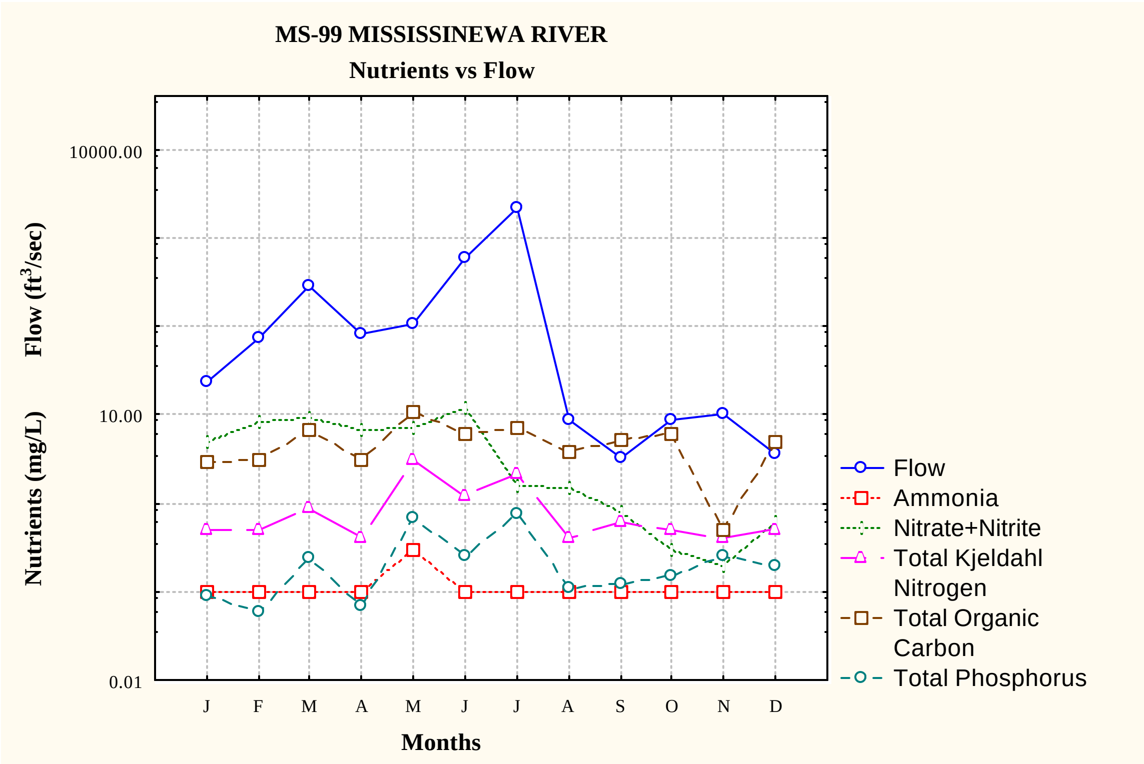



MISSISSINEWA RIVER
Fixed Station Monitoring Program 1998
Total Kjeldahl Nitrogen (mg/L)
3.4
3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
MS-99
MS-68
MS-36
MS-28
MS-1
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

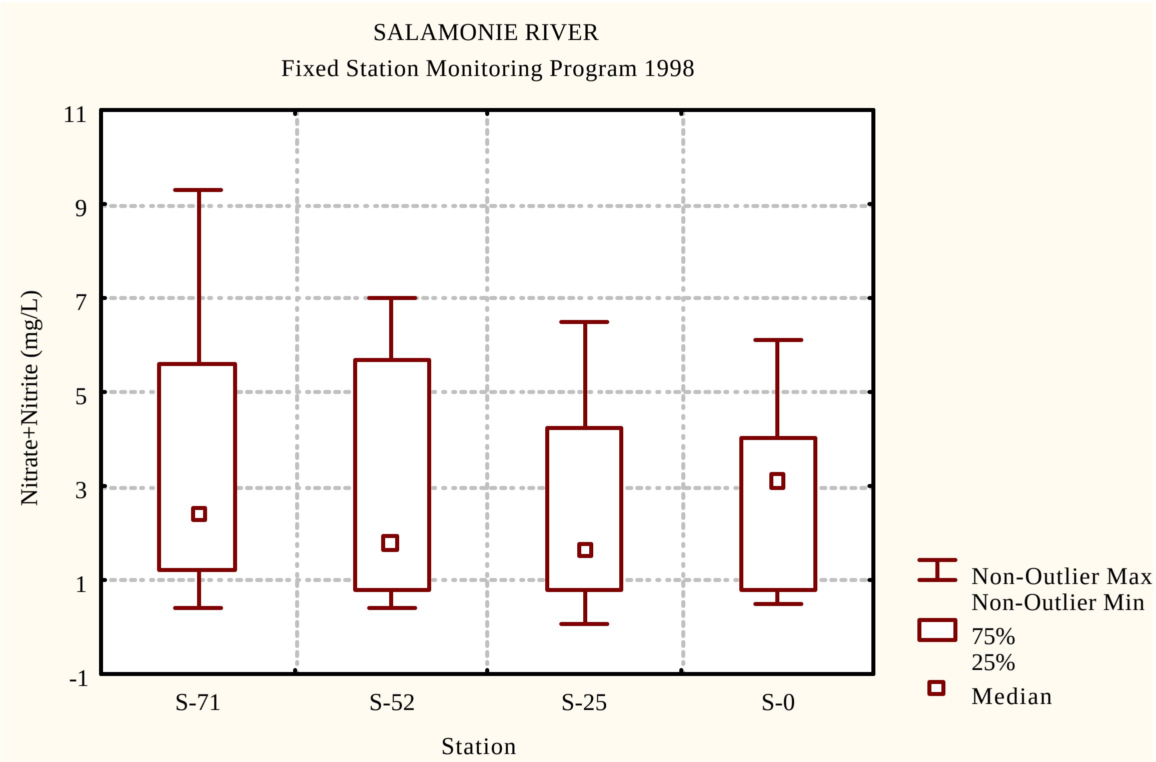

MISSISSINEWA RIVER
Fixed Station Monitoring Program 1998
Total Organic Carbon
12
10
8
6
4
2
0
-2
MS-99
MS-68
MS-36
MS-28
MS-1
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median

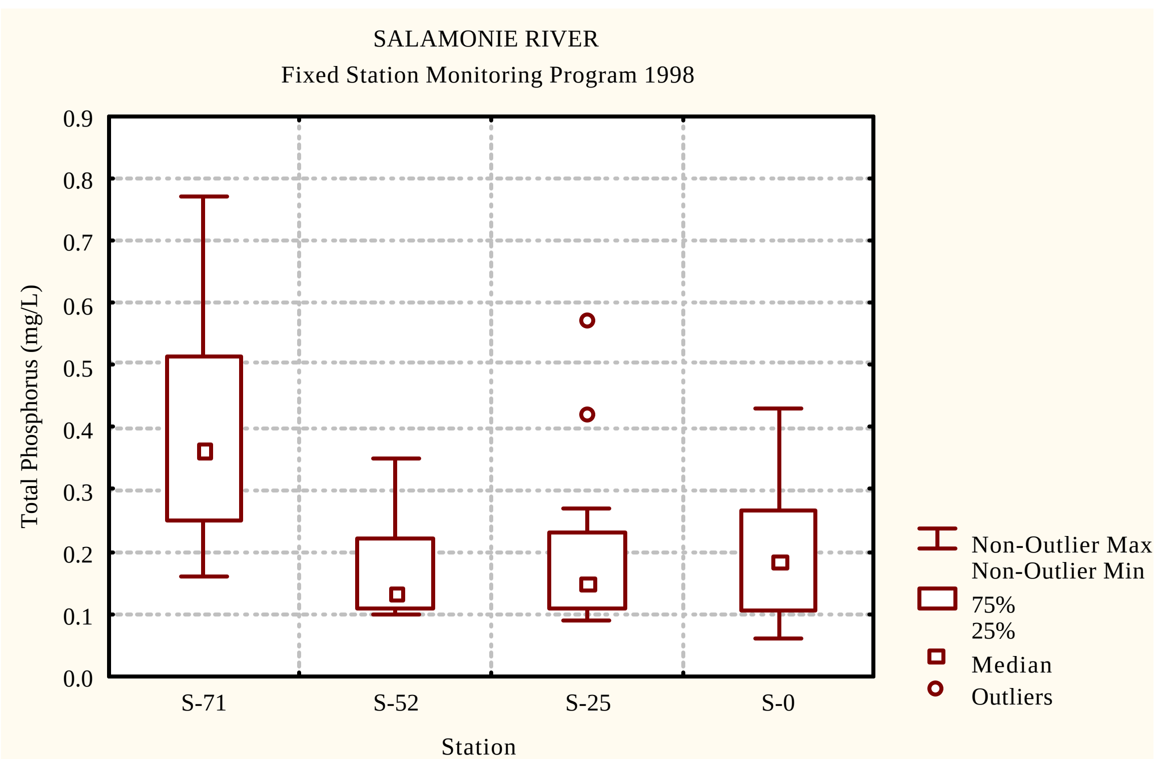

MS-1 MISSISSINEWA RIVER
Nutrients vs Flow
Flow (ft³/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

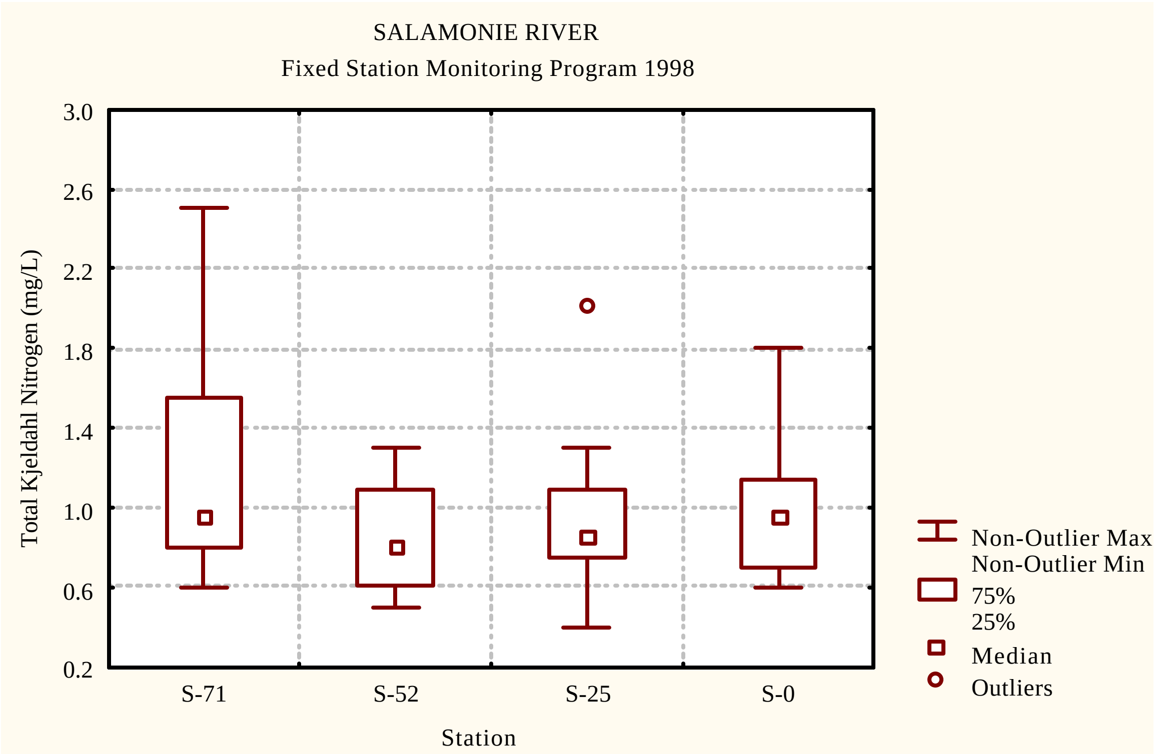

MS-36 MISSISSINEWA RIVER
Nutrients vs Flow
Flow (ft³/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

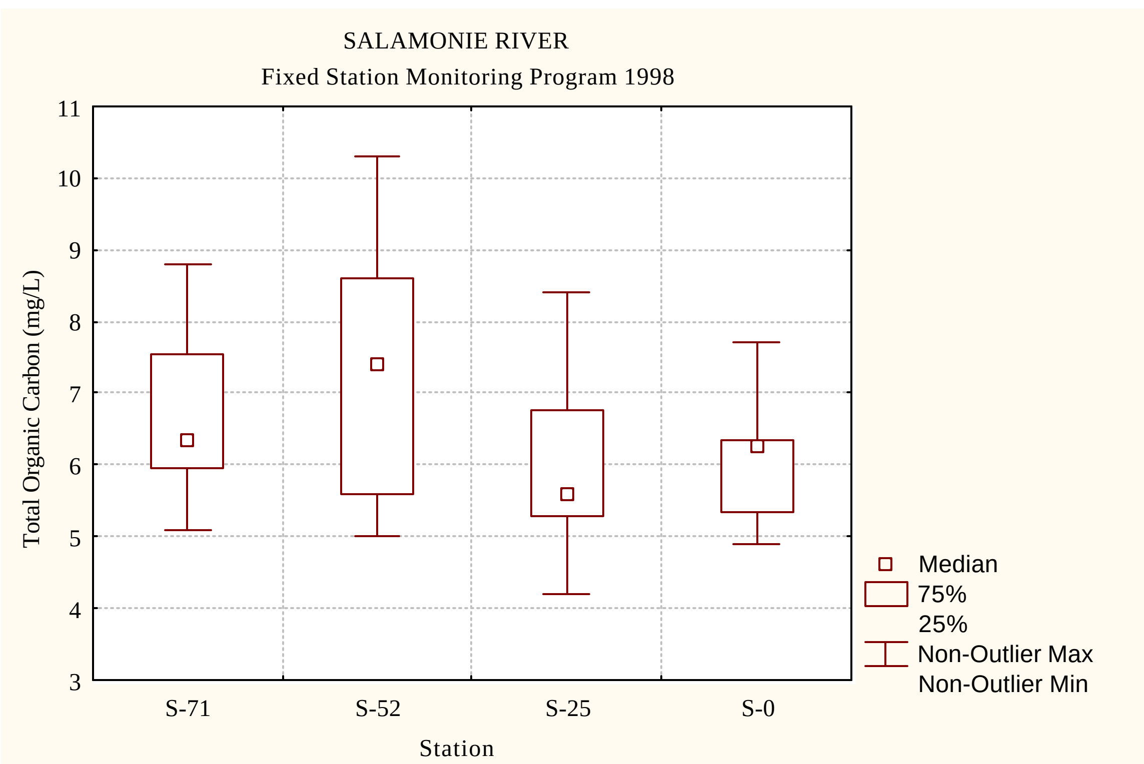

MS-99 MISSISSINEWA RIVER
Nutrients vs Flow
Flow (ft^3/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J
F
M
A
M
J
J
A
S
O
N
D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

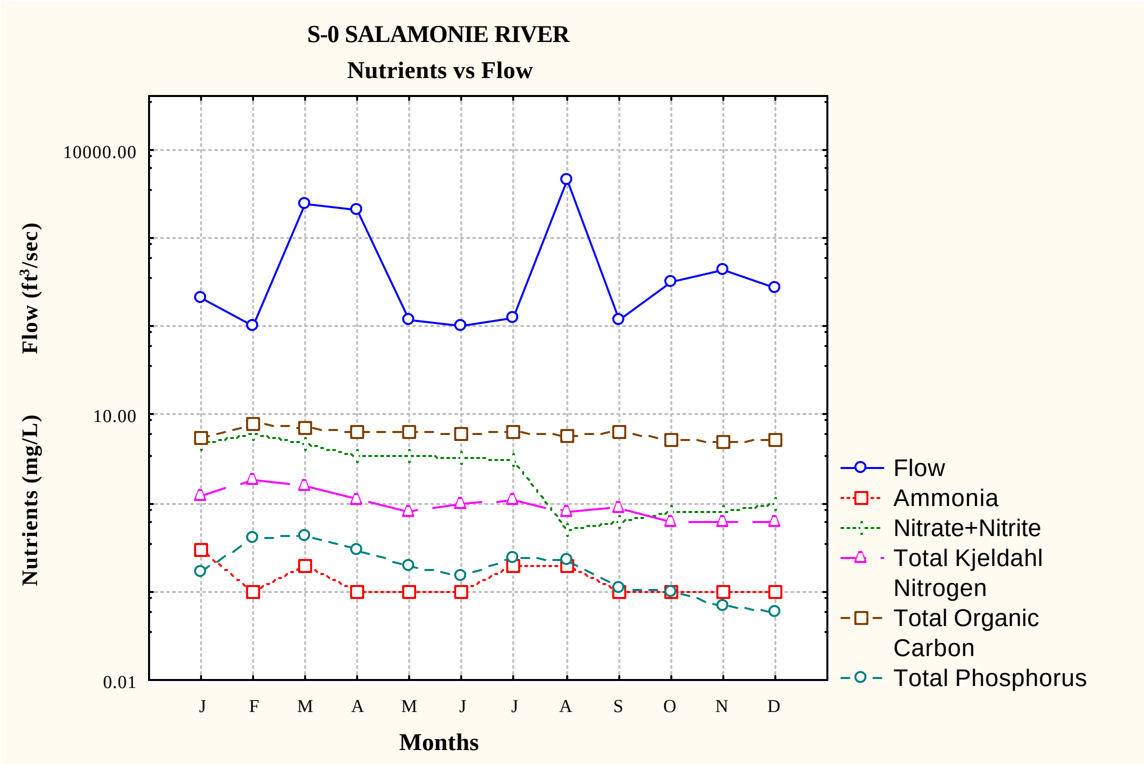
Appendix D Selected Water Quality Parameters in the Salamonie River Basin

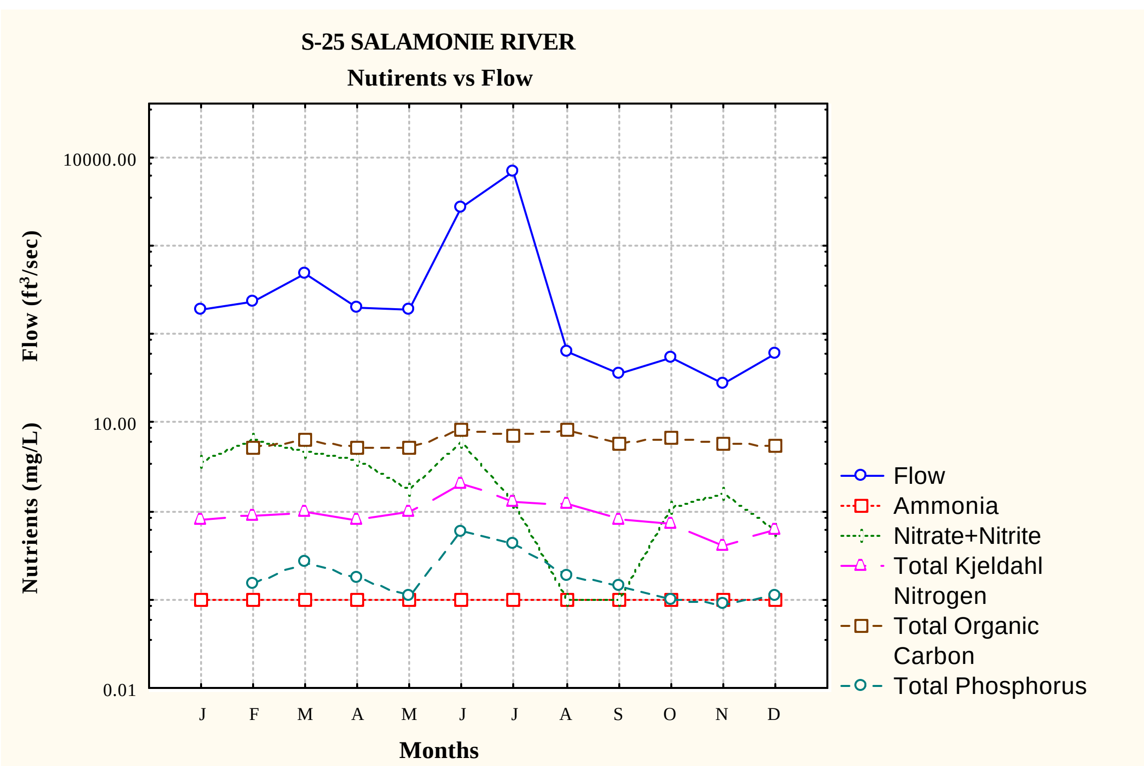


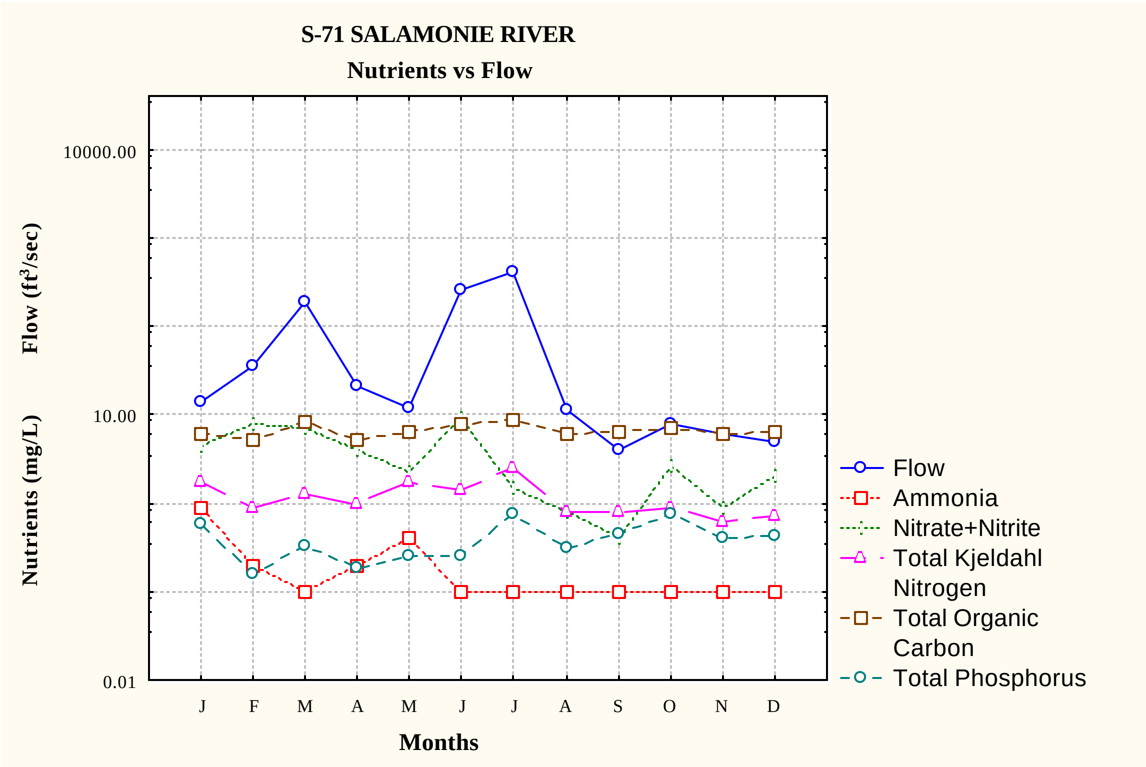



SALAMONIE RIVER
Fixed Station Monitoring Program 1998
Total Kjeldahl Nitrogen (mg/L)
3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
S-71
S-52
S-25
S-0
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers

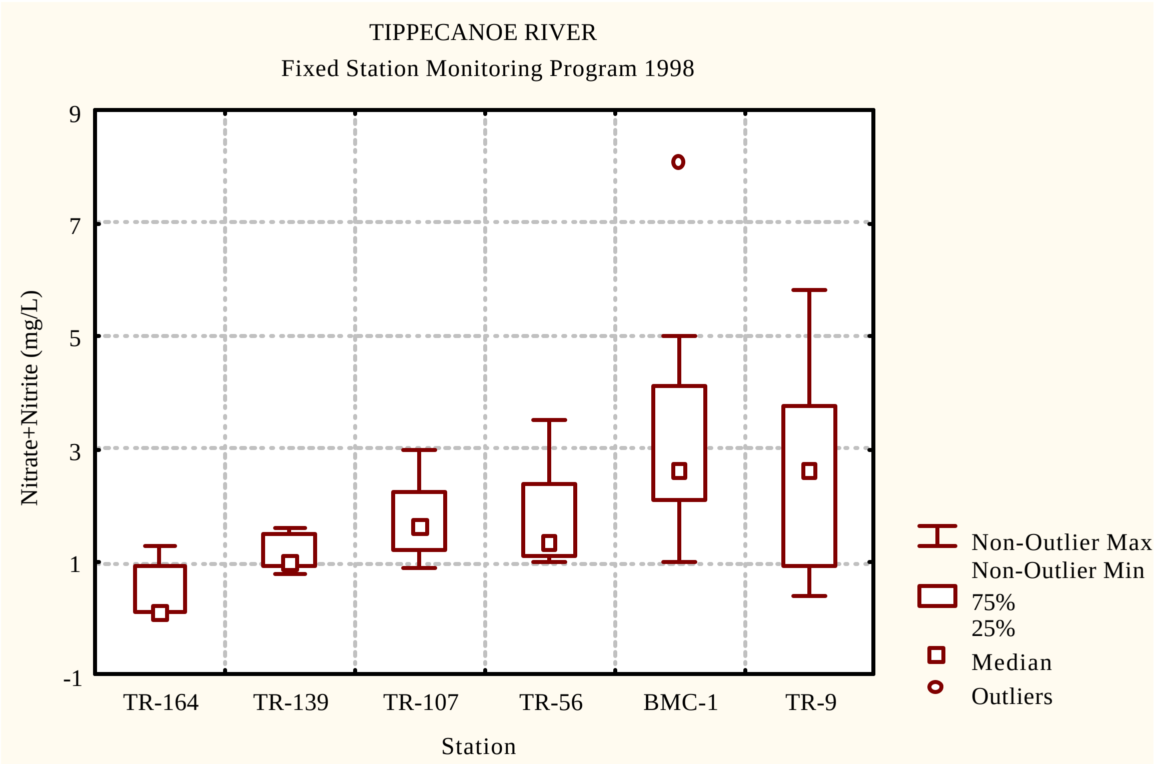

SALAMONIE RIVER
Fixed Station Monitoring Program 1998
Total Organic Carbon (mg/L)
11
10
9
8
7
6
5
4
3
S-71
S-52
S-25
S-0
Station
Median
75%
25%
Non-Outlier Max
Non-Outlier Min

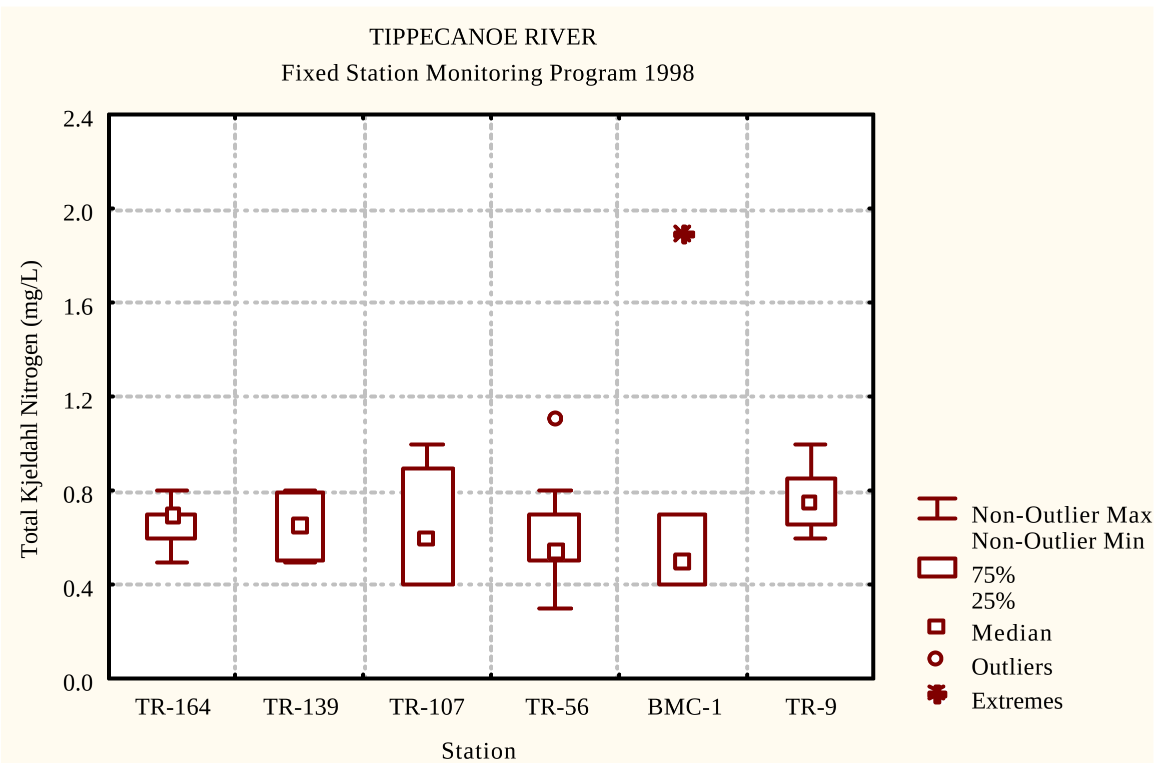

S-0 SALAMONIE RIVER
Nutrients vs Flow
Flow (ft³/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

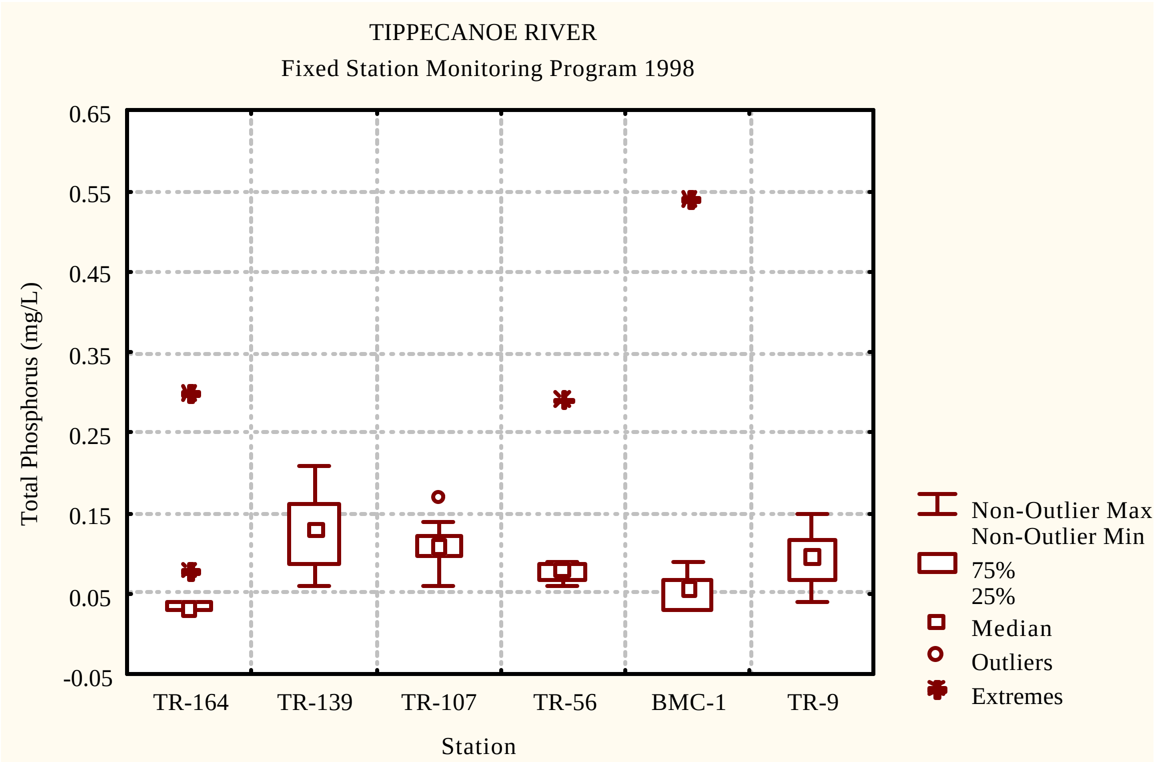

S-25 SALAMONIE RIVER
Nutirents vs Flow
Flow (ft³/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

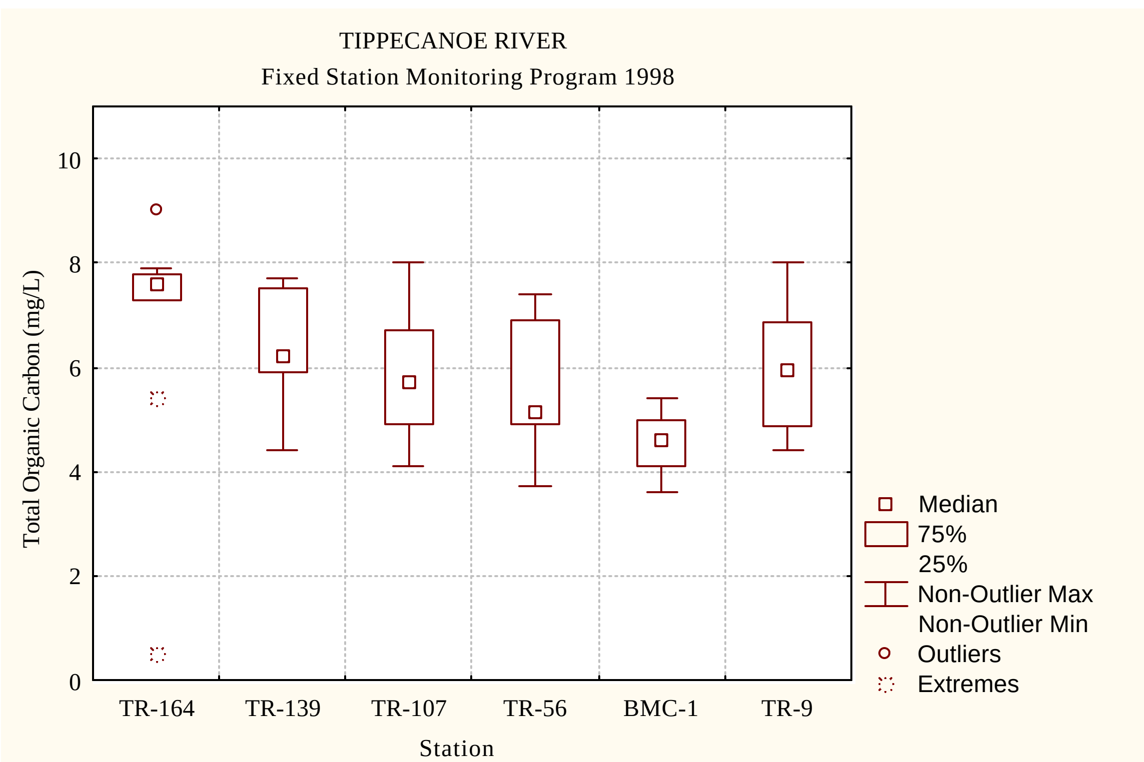

S-71 SALAMONIE RIVER
Nutrients vs Flow
Flow (ft³/sec)
Nutrients (mg/L)
10000.00
10.00
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

Appendix E Selected Water Quality Parameters in the Tippecanoe River Basin

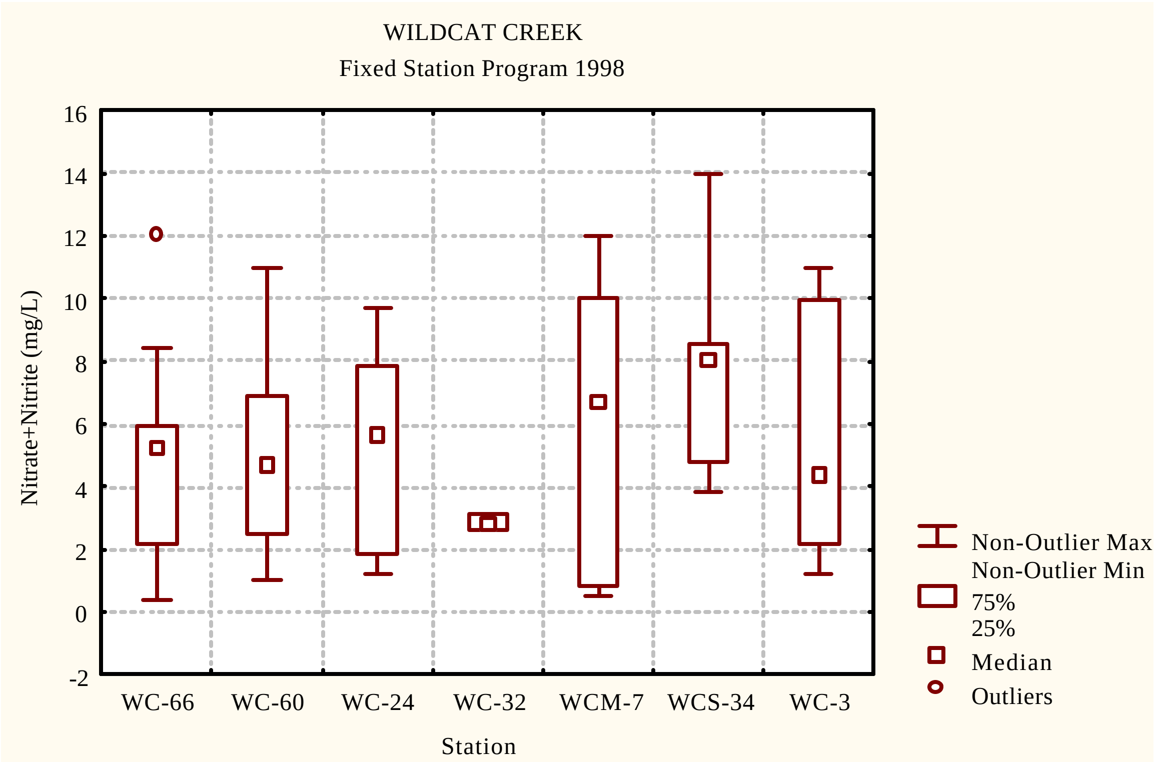


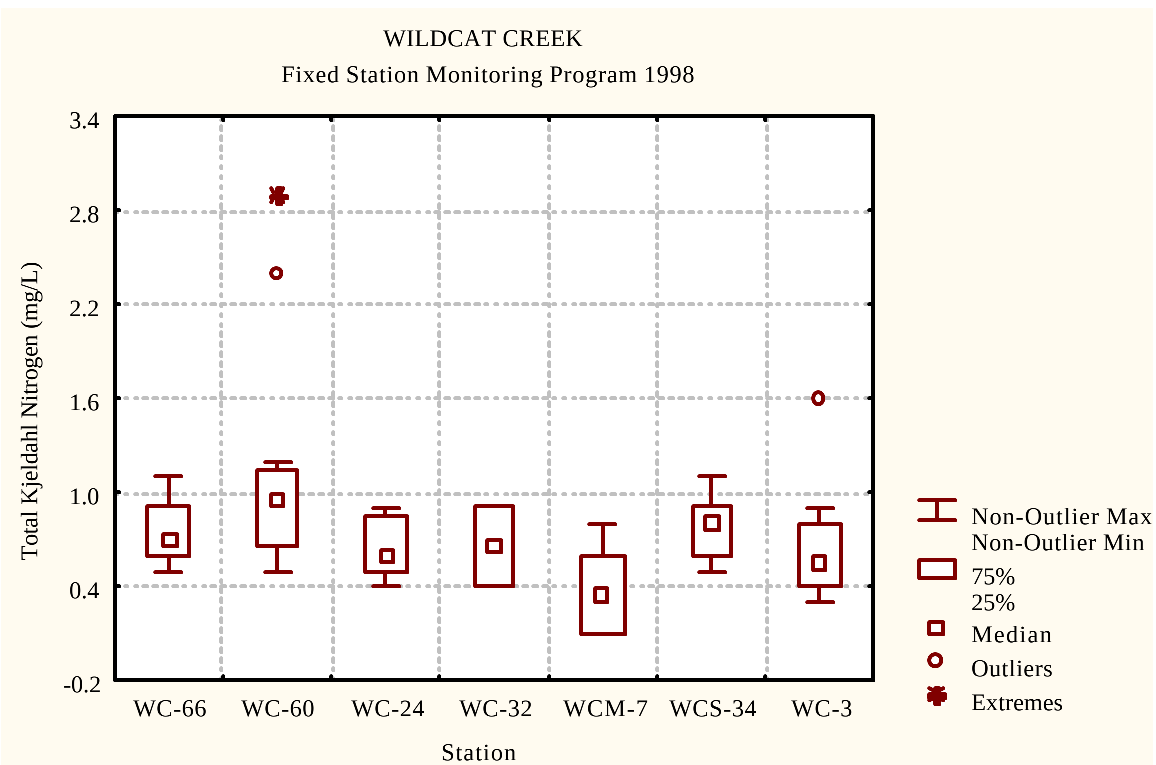


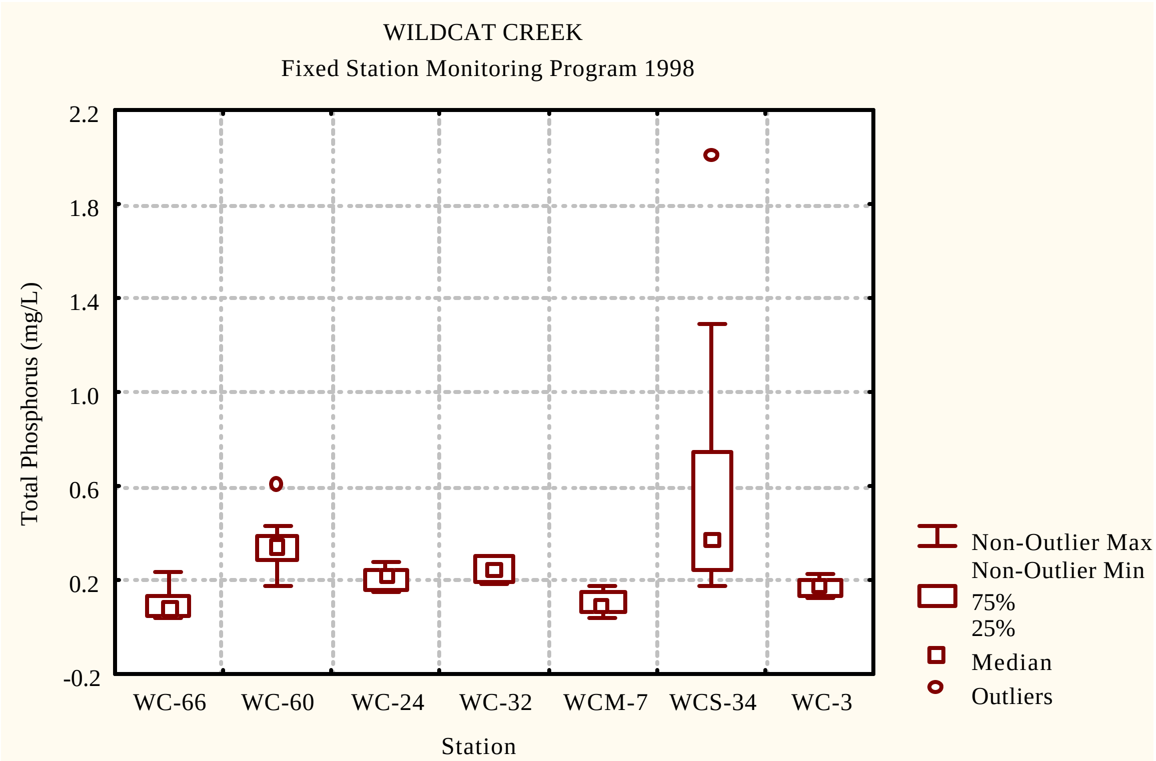

TIPPECANOE RIVER
Fixed Station Monitoring Program 1998
Total Phosphorus (mg/L)
0.65
0.55
0.45
0.35
0.25
0.15
0.05
-0.05
TR-164
TR-139
TR-107
TR-56
BMC-1
TR-9
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

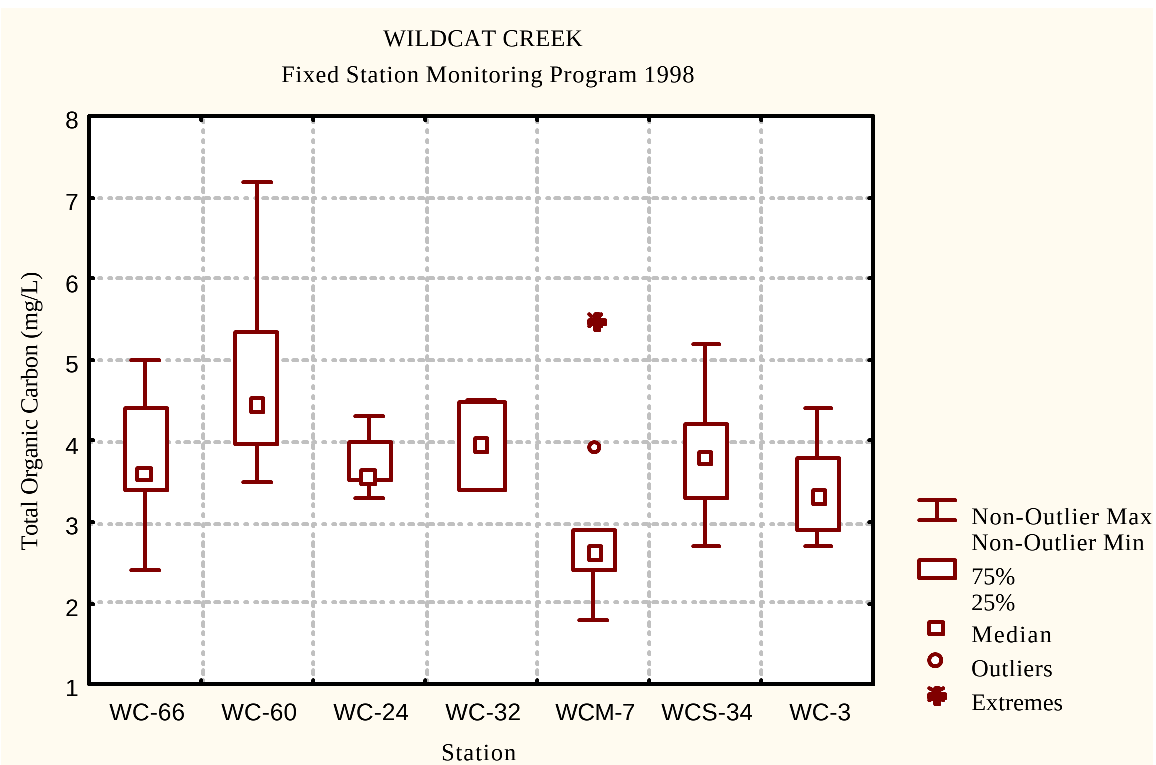

TIPPECANOE RIVER
Fixed Station Monitoring Program 1998
Total Organic Carbon (mg/L)
10
8
6
4
2
0
TR-164
TR-139
TR-107
TR-56
BMC-1
TR-9
Station
Median
75%
25%
Non-Outlier Max
Non-Outlier Min
Outliers
Extremes

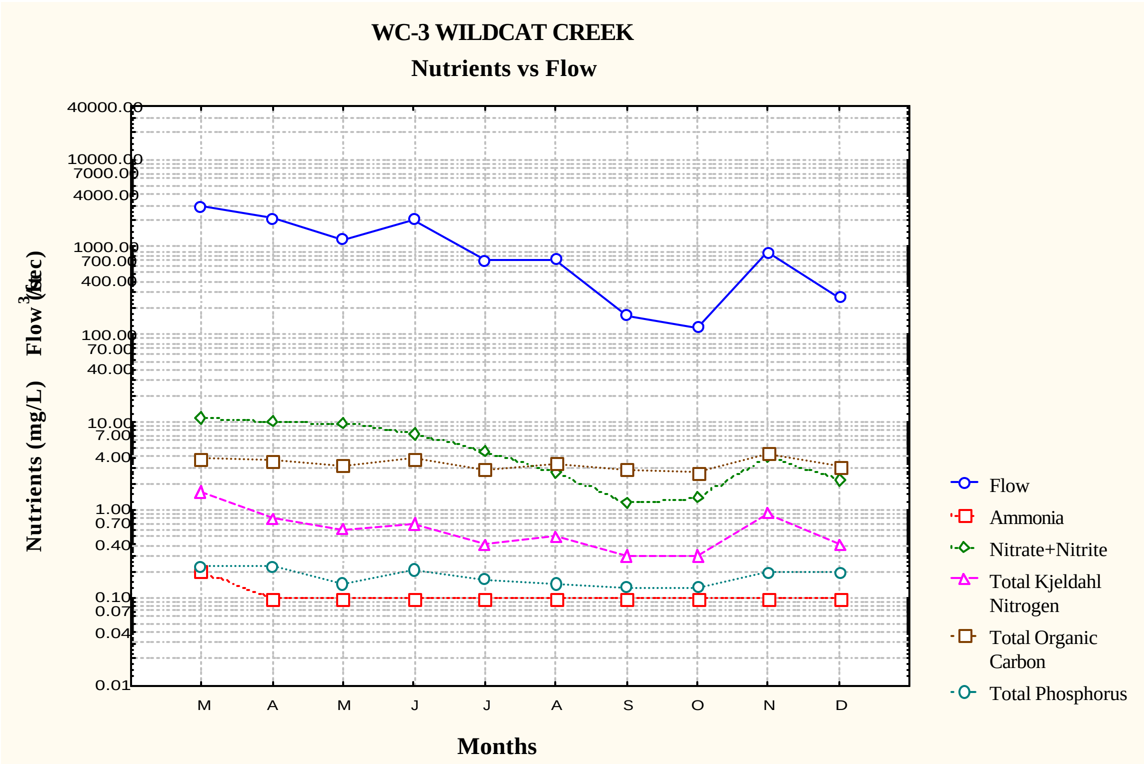
Appendix F Selected Water Quality Parameters in the Wildcat Creek River Basin

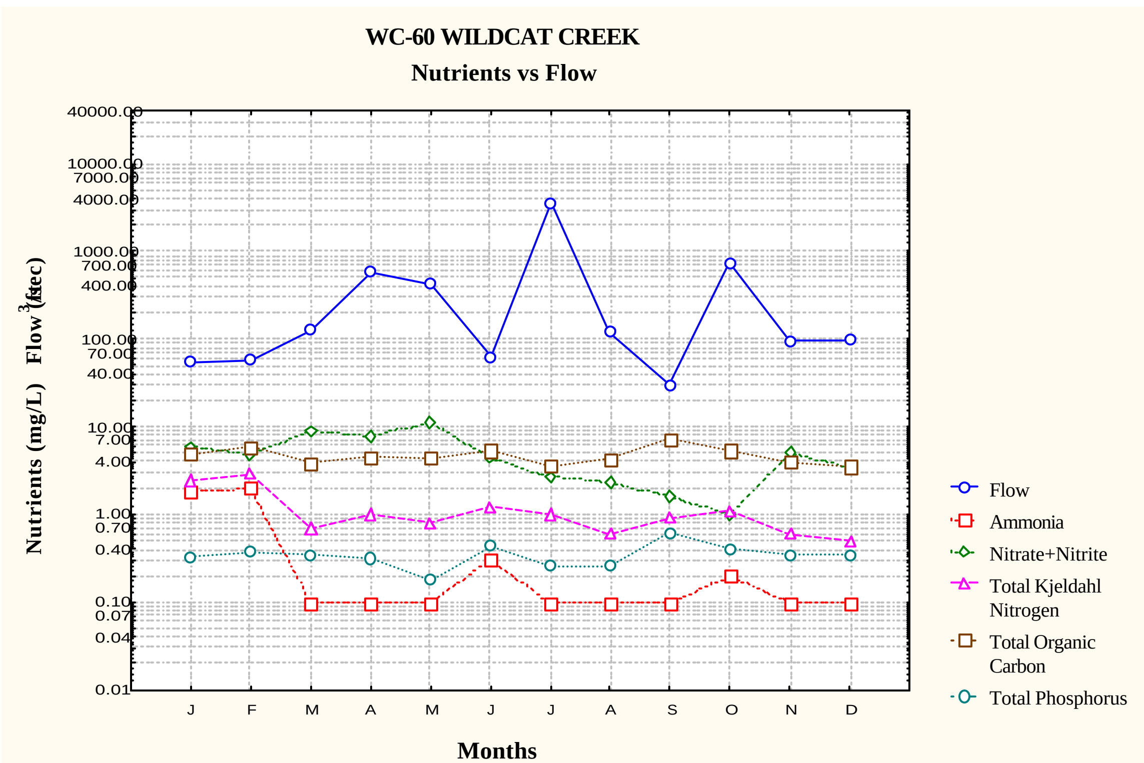





WILDCAT CREEK
Fixed Station Monitoring Program 1998
Total Phosphorus (mg/L)
2.2
1.8
1.4
1.0
0.6
0.2
-0.2
WC-66
WC-60
WC-24
WC-32
WCM-7
WCS-34
WC-3
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers


WILDCAT CREEK
Fixed Station Monitoring Program 1998
Total Organic Carbon (mg/L)
8
7
6
5
4
3
2
1
WC-66
WC-60
WC-24
WC-32
WCM-7
WCS-34
WC-3
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes


WC-3 WILDCAT CREEK
Nutrients vs Flow
Nutrients (mg/L) Flow (ft³/sec)
Months
M A M J J A S O N D
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus


WC-60 WILDCAT CREEK
Nutrients vs Flow
Nutrients (mg/L) Flow (ft³/sec)
Months
J F M A M J J A S O N D
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

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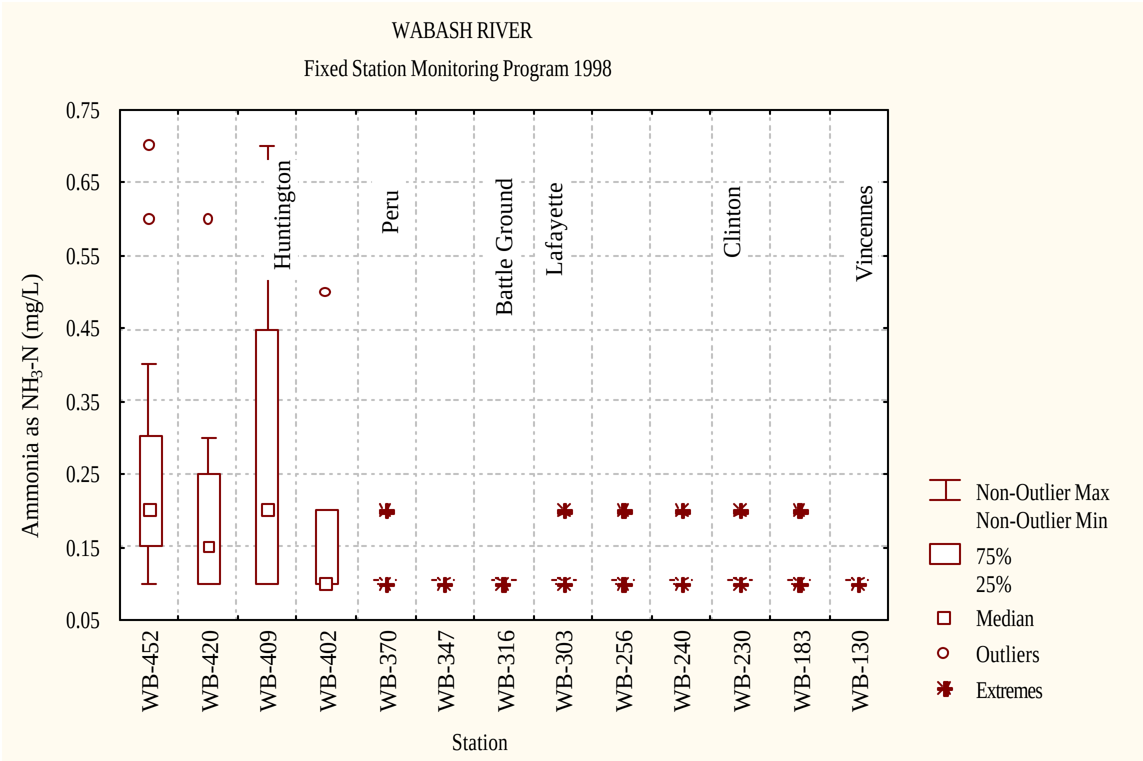
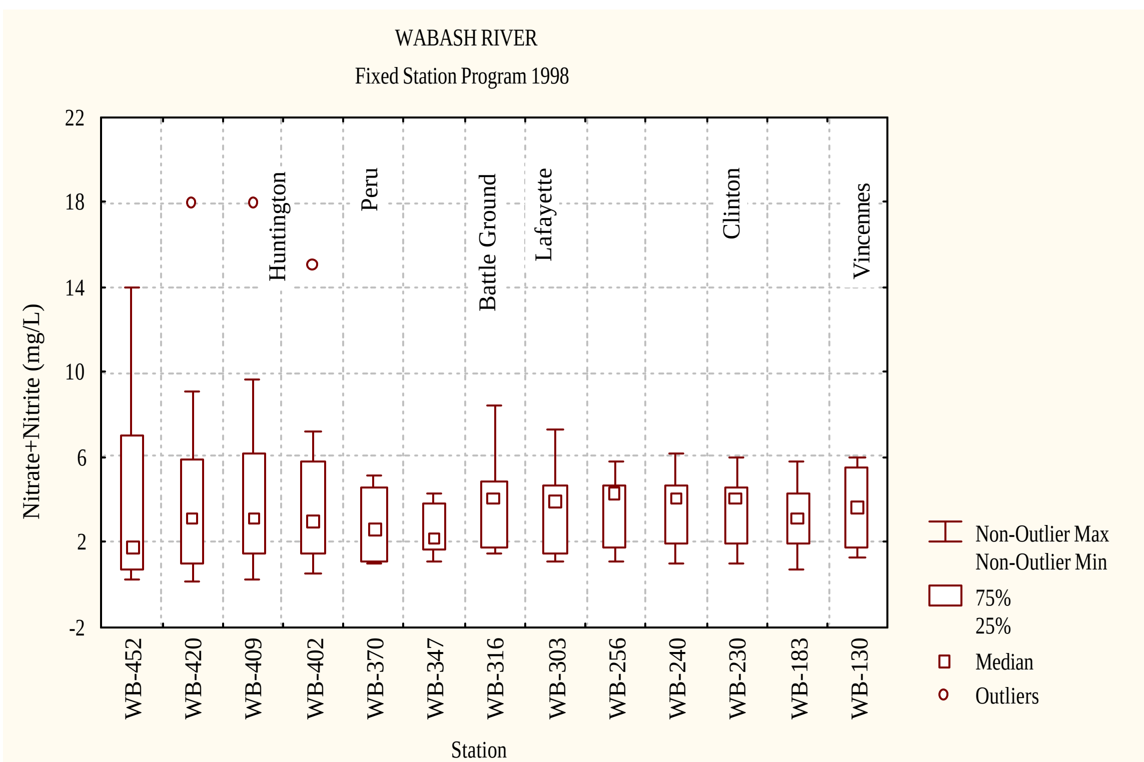
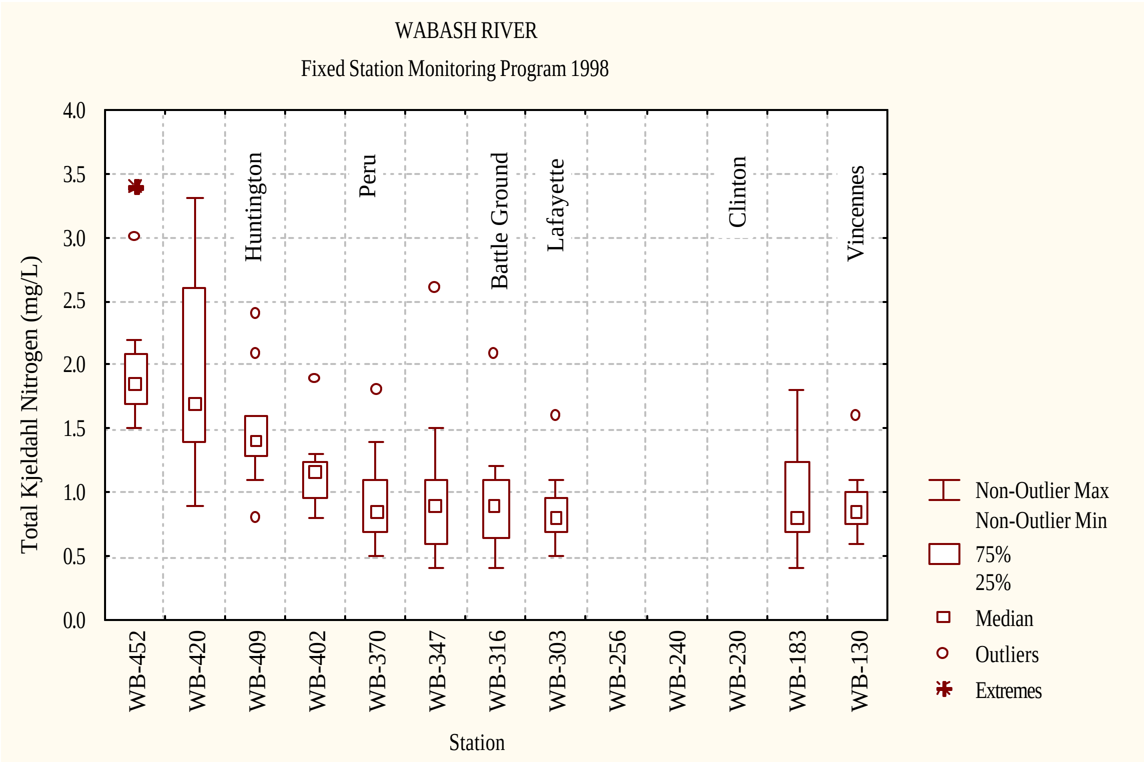
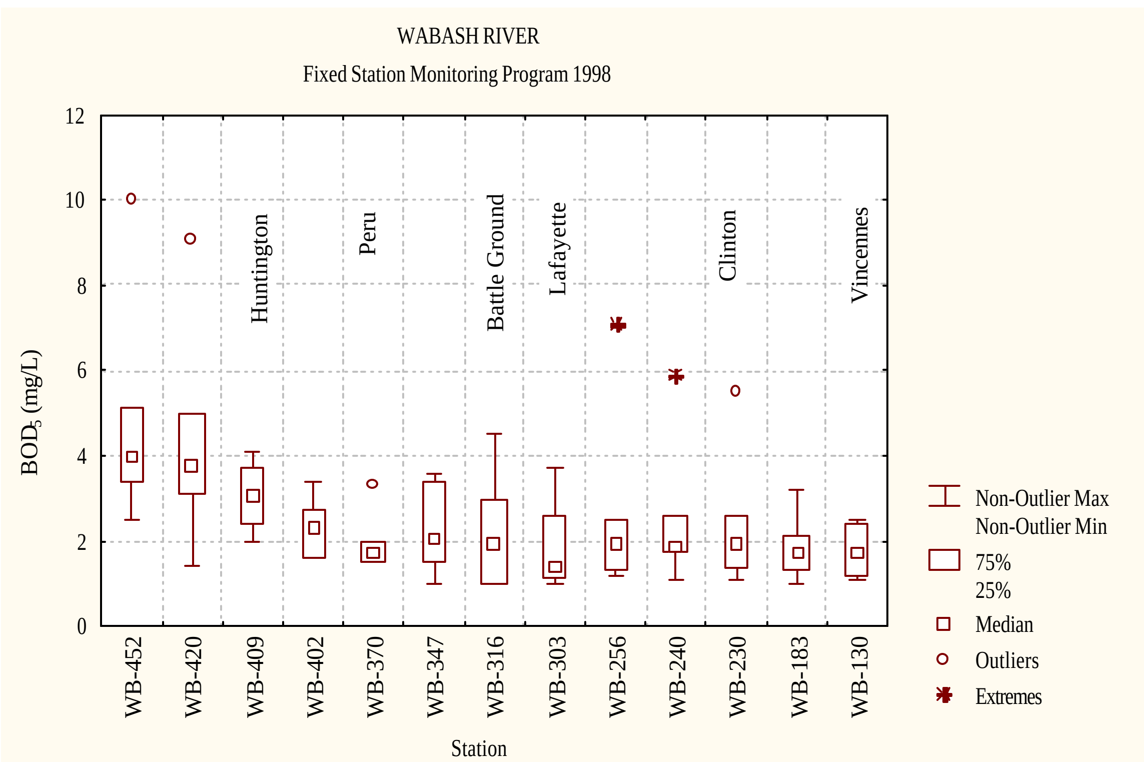
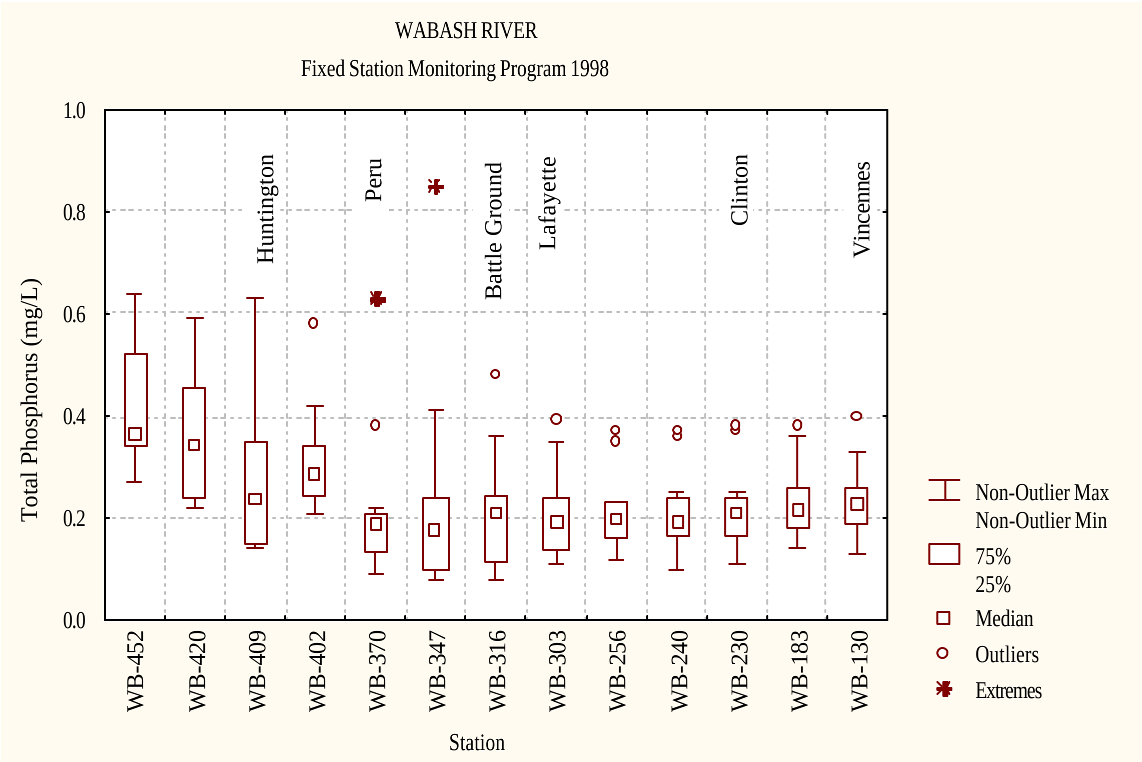
Appendix G Selected Water Quality Parameters in the Wabash River Basin

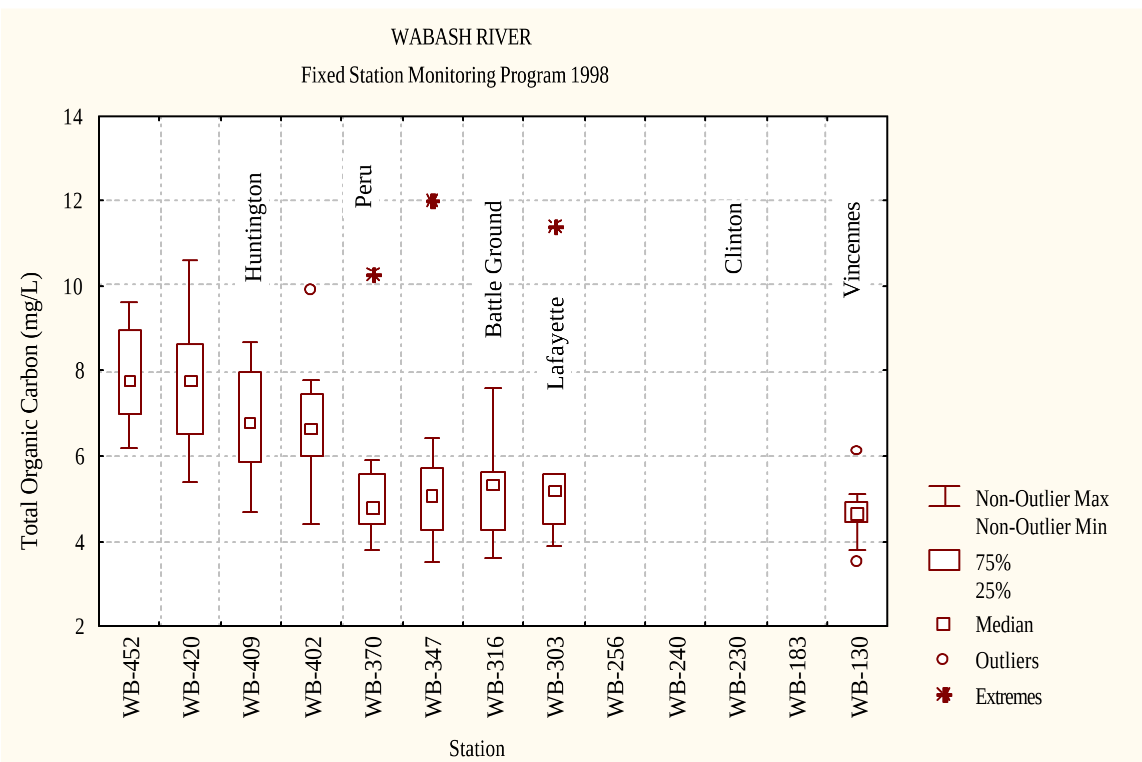


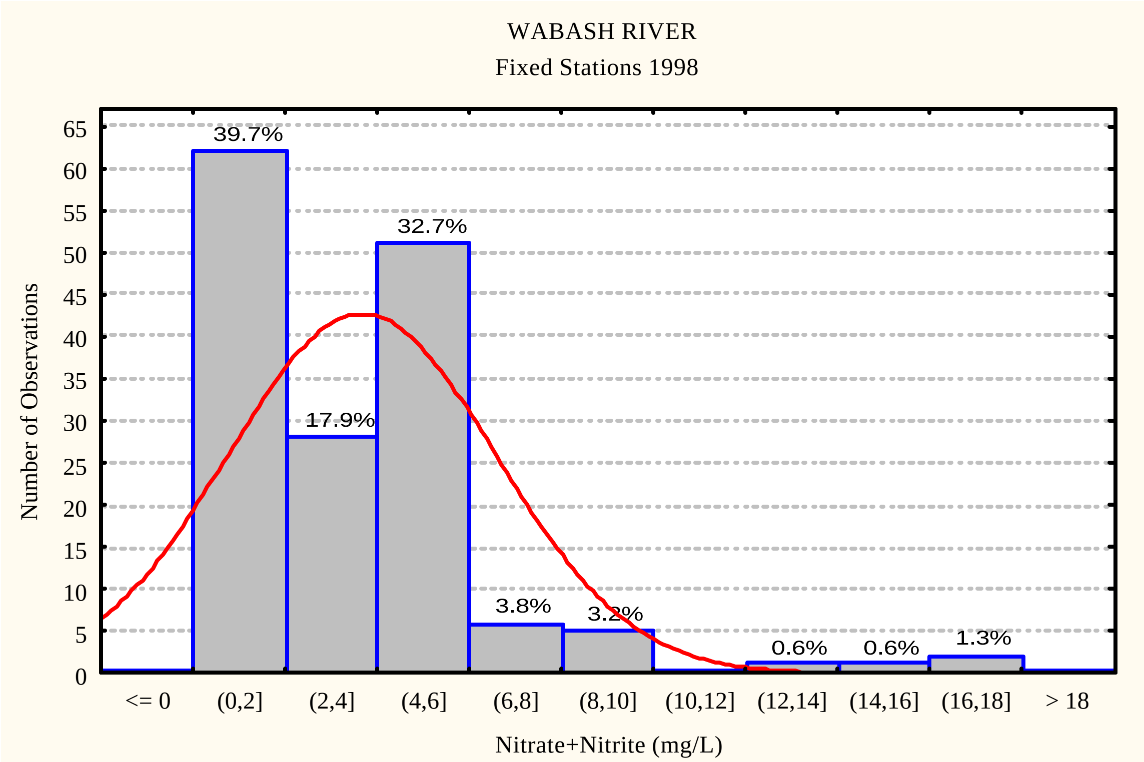


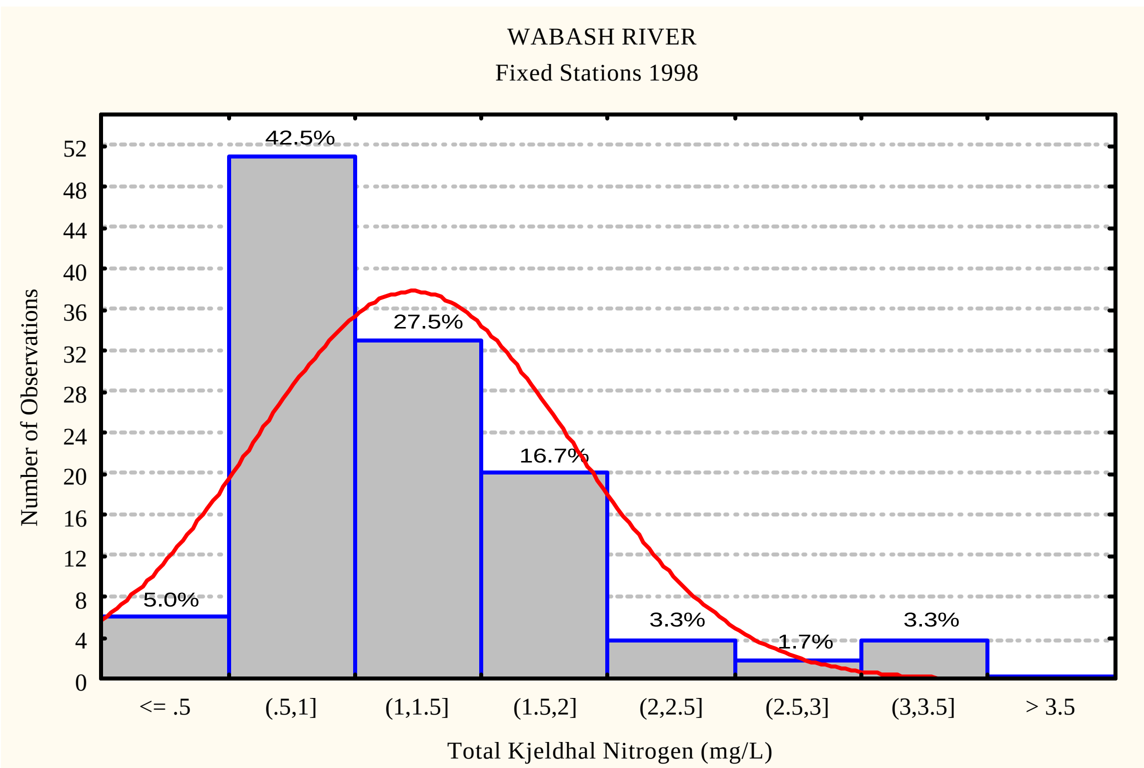

WABASH RIVER
Fixed Station Monitoring Program 1998
Total Kjeldahl Nitrogen (mg/L)
Huntington
Peru
Battle Ground
Lafayette
Clinton
Vincennes
WB-452
WB-420
WB-409
WB-402
WB-370
WB-347
WB-316
WB-303
WB-256
WB-240
WB-230
WB-183
WB-130
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

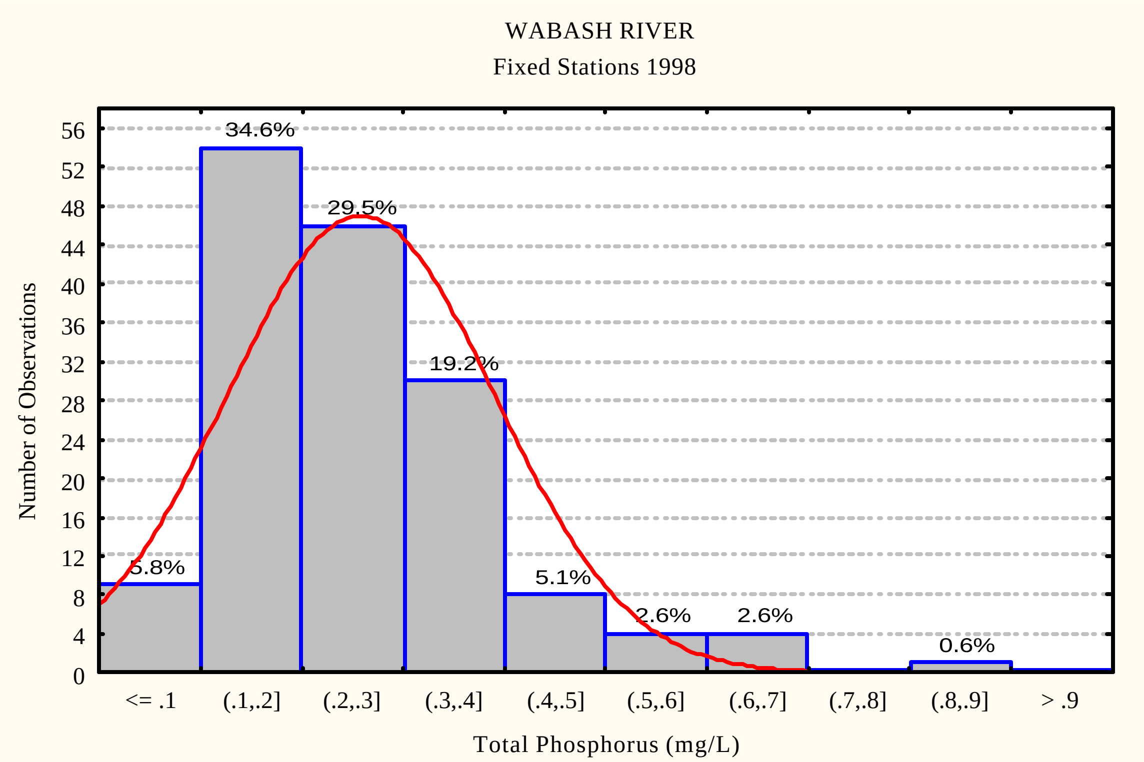

WABASH RIVER
Fixed Station Monitoring Program 1998
BOD_5 (mg/L)
Huntington
Peru
Battle Ground
Lafayette
Clinton
Vincennes
WB-452
WB-420
WB-409
WB-402
WB-370
WB-347
WB-316
WB-303
WB-256
WB-240
WB-230
WB-183
WB-130
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

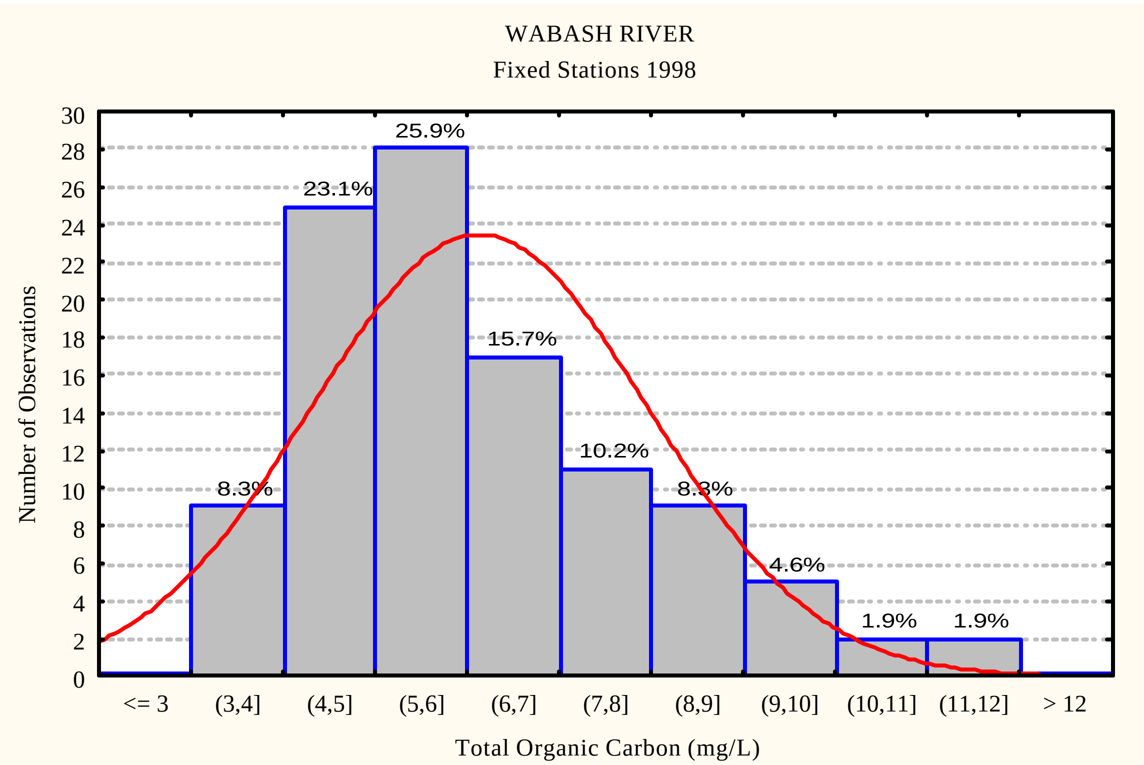

WABASH RIVER
Fixed Station Monitoring Program 1998
Total Phosphorus (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
Huntington
Peru
Battle Ground
Lafayette
Clinton
Vincennes
WB-452
WB-420
WB-409
WB-402
WB-370
WB-347
WB-316
WB-303
WB-256
WB-240
WB-230
WB-183
WB-130
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

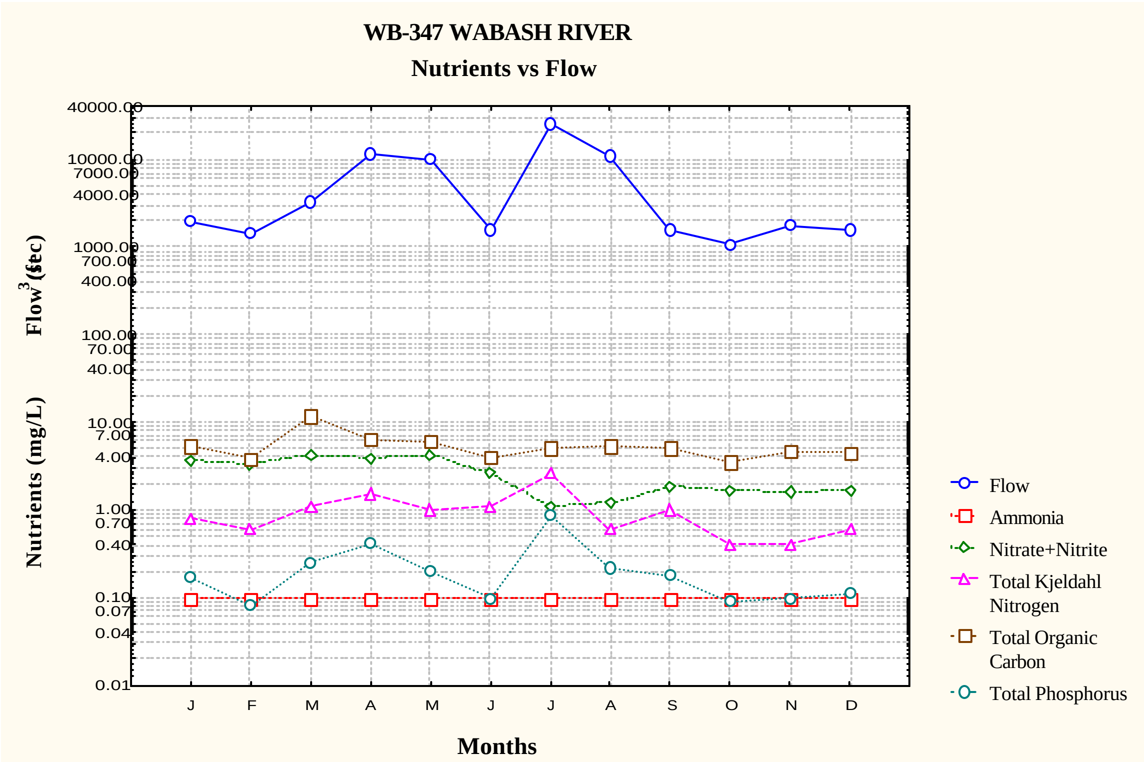

WABASH RIVER
Fixed Station Monitoring Program 1998
Total Organic Carbon (mg/L)
14
12
10
8
6
4
2
Huntington
Peru
Battle Ground
Lafayette
Clinton
Vincennes
WB-452
WB-420
WB-409
WB-402
WB-370
WB-347
WB-316
WB-303
WB-256
WB-240
WB-230
WB-183
WB-130
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

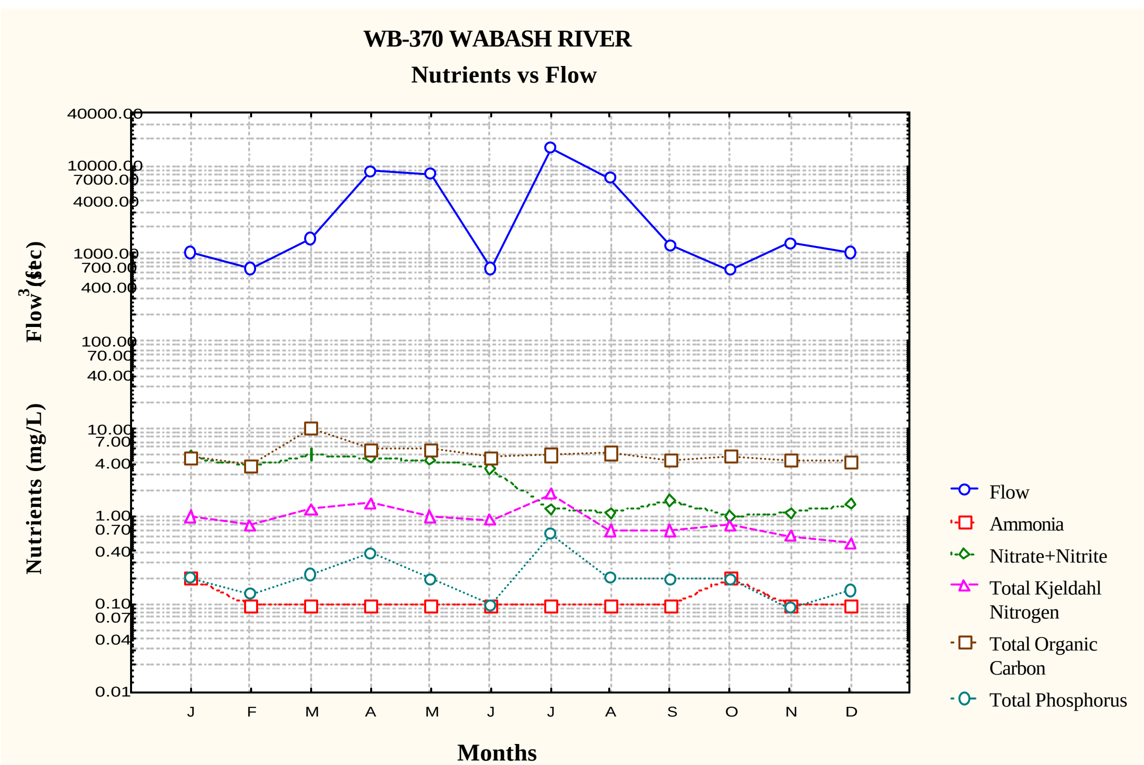

WABASH RIVER
Fixed Stations 1998
Number of Observations
65
60
55
50
45
40
35
30
25
20
15
10
5
0
39.7%
17.9%
32.7%
3.8%
3.2%
0.6%
0.6%
1.3%
<= 0
(0,2]
(2,4]
(4,6]
(6,8]
(8,10]
(10,12]
(12,14]
(14,16]
(16,18]
> 18
Nitrate+Nitrite (mg/L)

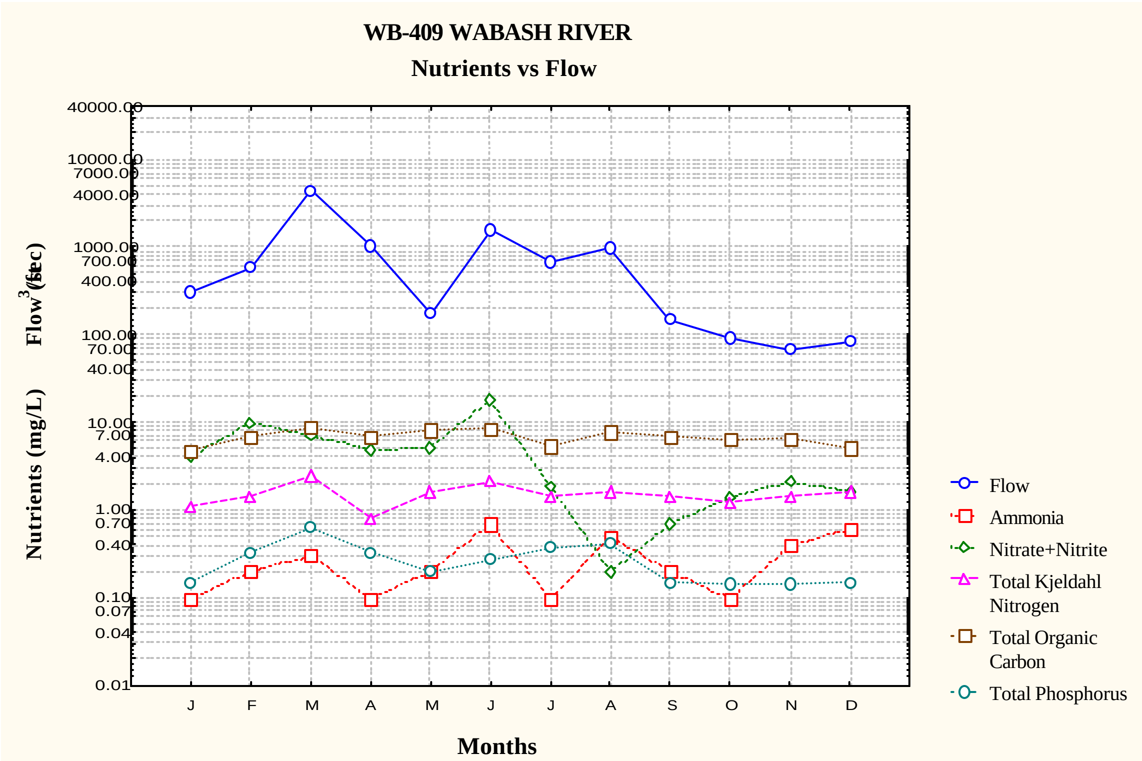

WABASH RIVER
Fixed Stations 1998
Number of Observations
52
48
44
40
36
32
28
24
20
16
12
8
4
0
5.0%
42.5%
27.5%
16.7%
3.3%
1.7%
3.3%
<= .5
(.5,1]
(1,1.5]
(1.5,2]
(2,2.5]
(2.5,3]
(3,3.5]
> 3.5
Total Kjeldhal Nitrogen (mg/L)

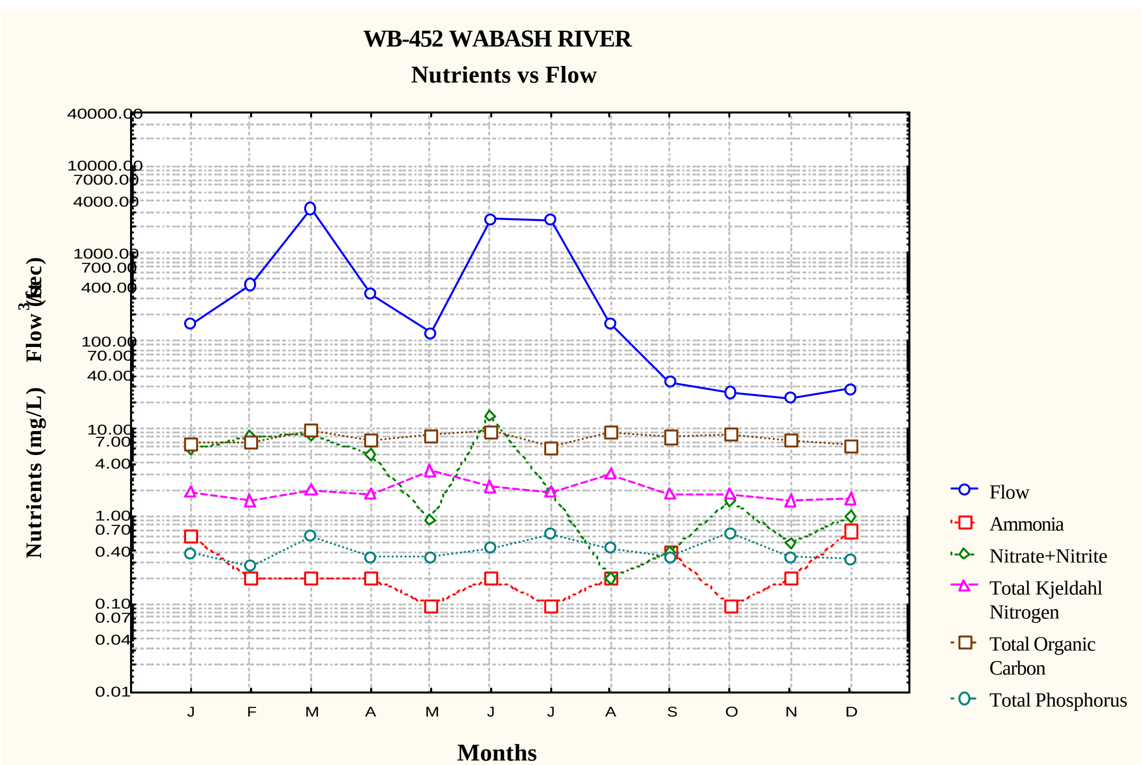

WABASH RIVER
Fixed Stations 1998
Number of Observations
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
5.8%
34.6%
29.5%
19.2%
5.1%
2.6%
2.6%
0.6%
<= .1
(.1,.2]
(.2,.3]
(.3,.4]
(.4,.5]
(.5,.6]
(.6,.7]
(.7,.8]
(.8,.9]
> .9
Total Phosphorus (mg/L)


WABASH RIVER
Fixed Stations 1998
Number of Observations
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
8.3%
23.1%
25.9%
15.7%
10.2%
8.3%
4.6%
1.9%
1.9%
<= 3
(3,4]
(4,5]
(5,6]
(6,7]
(7,8]
(8,9]
(9,10]
(10,11]
(11,12]
> 12
Total Organic Carbon (mg/L)


WB-347 WABASH RIVER
Nutrients vs Flow
Flow^3(sec)
Nutrients (mg/L)
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus


WB-370 WABASH RIVER
Nutrients vs Flow
Flow^3(sec)
Nutrients (mg/L)
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus


WB-409 WABASH RIVER
Nutrients vs Flow
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
Flow (ft³/sec)
Nutrients (mg/L)
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus


WB-452 WABASH RIVER
Nutrients vs Flow
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
Flow (ft³/sec)
Nutrients (mg/L)
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

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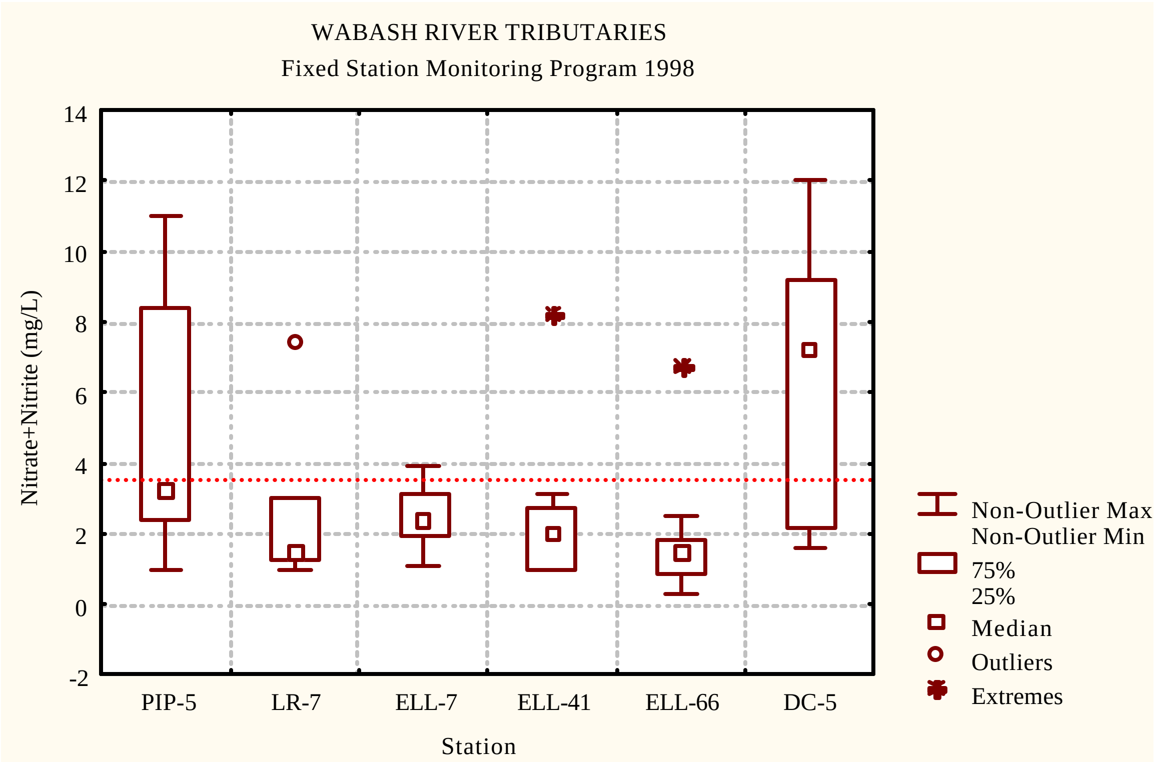
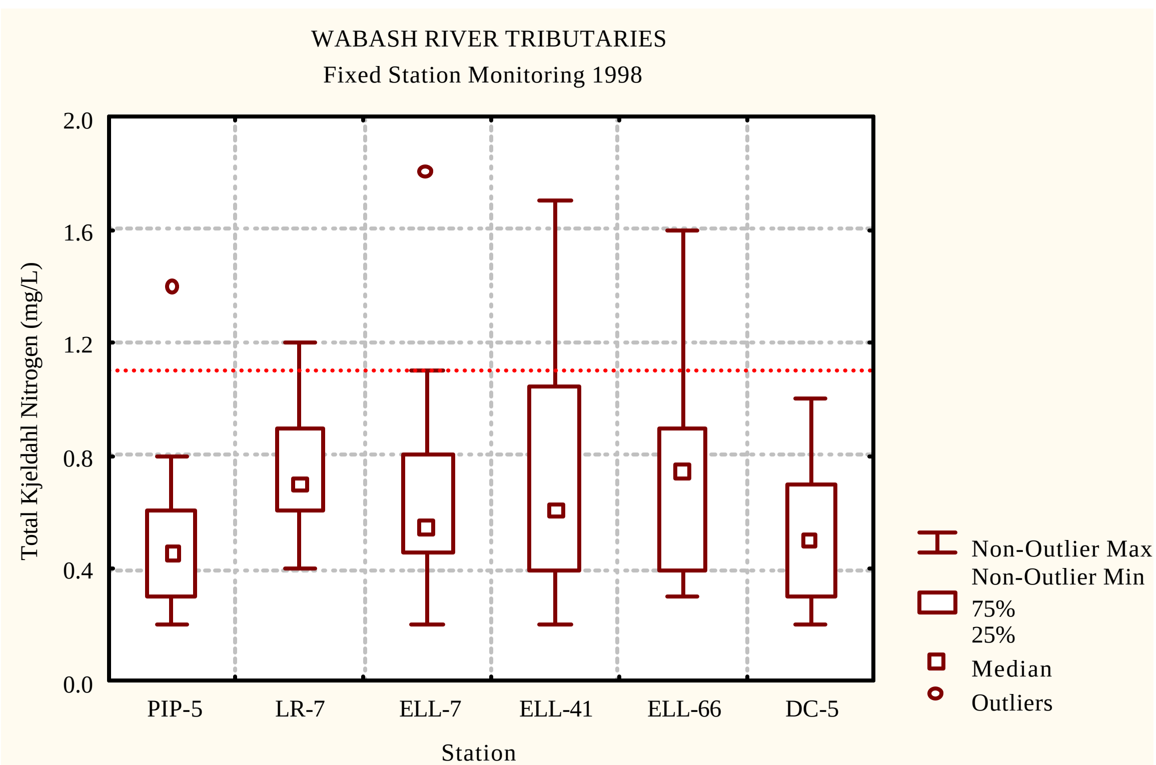
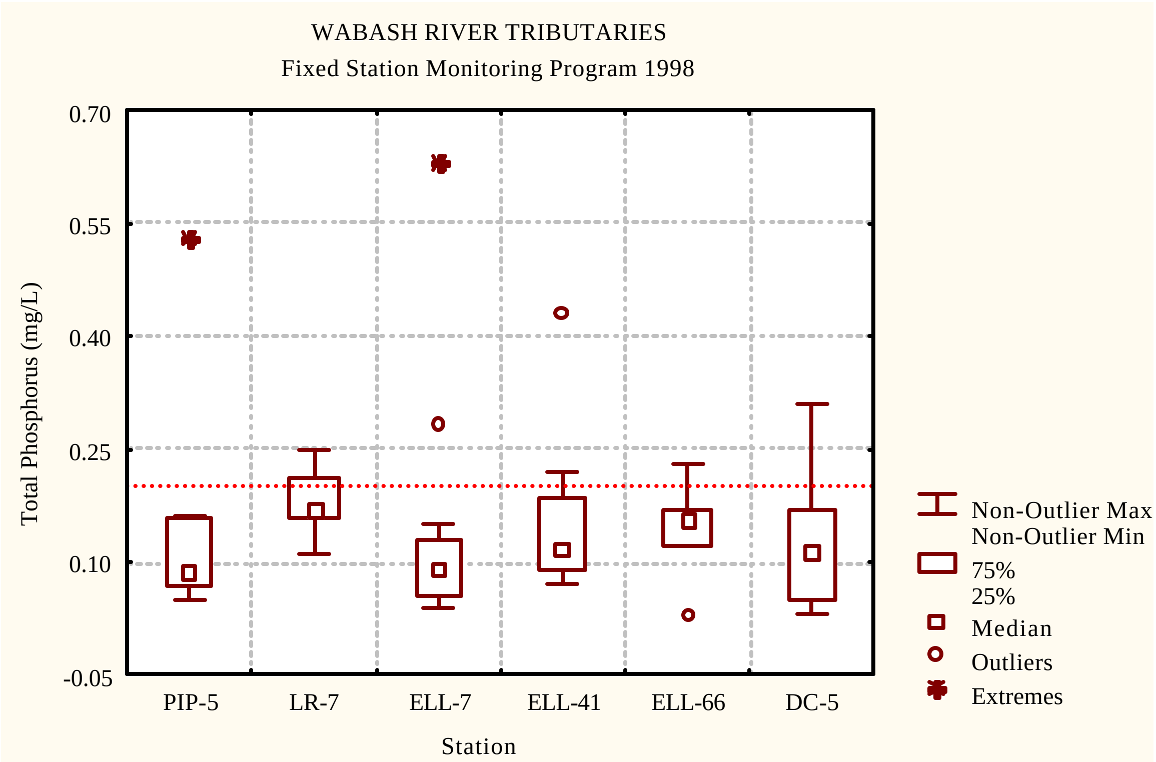
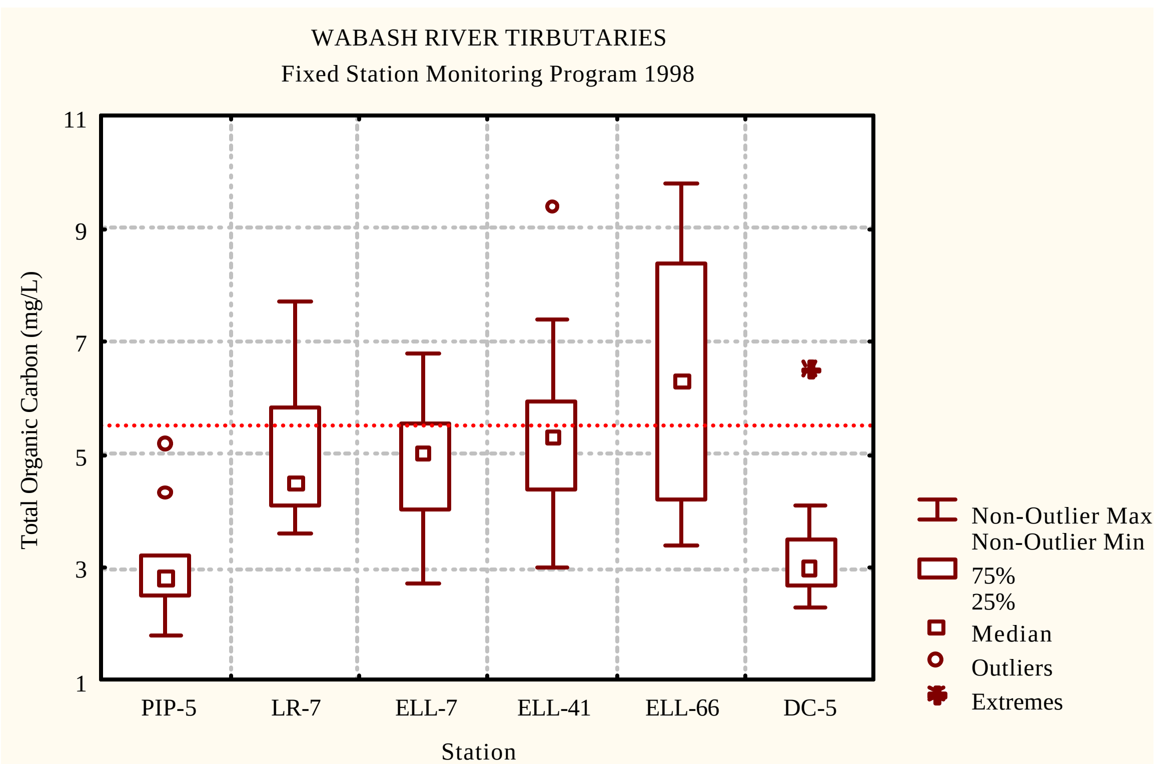
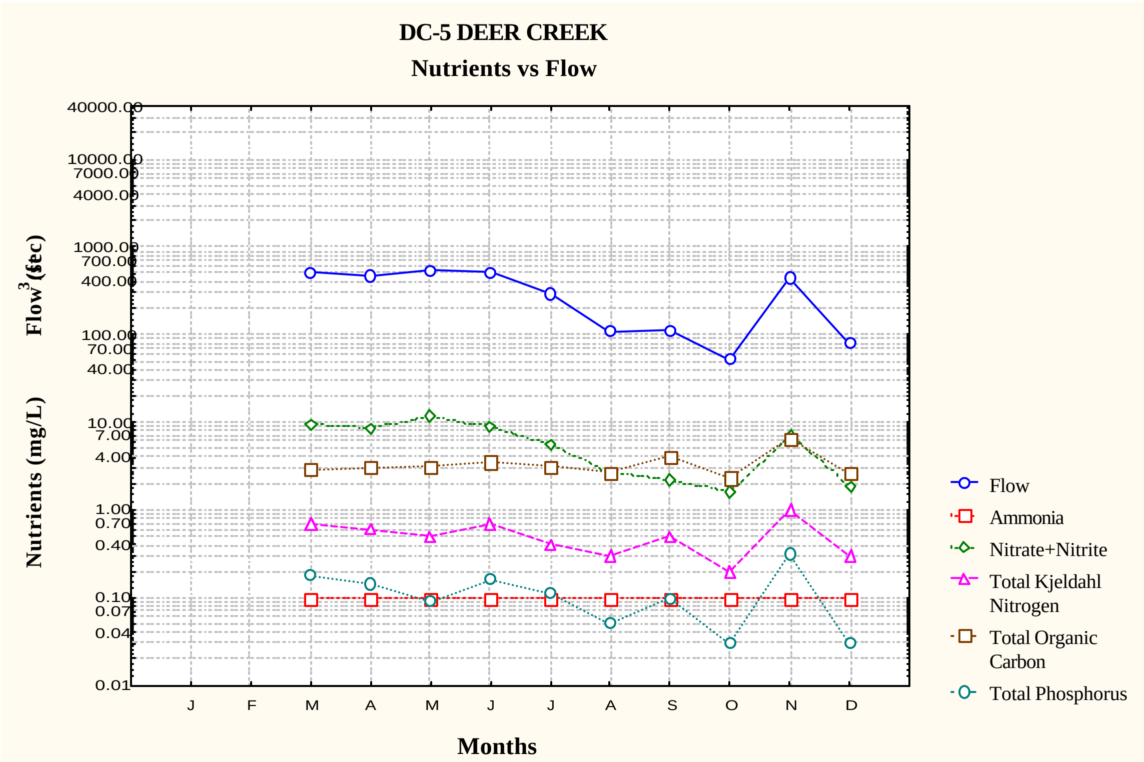
Appendix H Selected Water Quality Parameters from Tributaries in the Wabash Basin

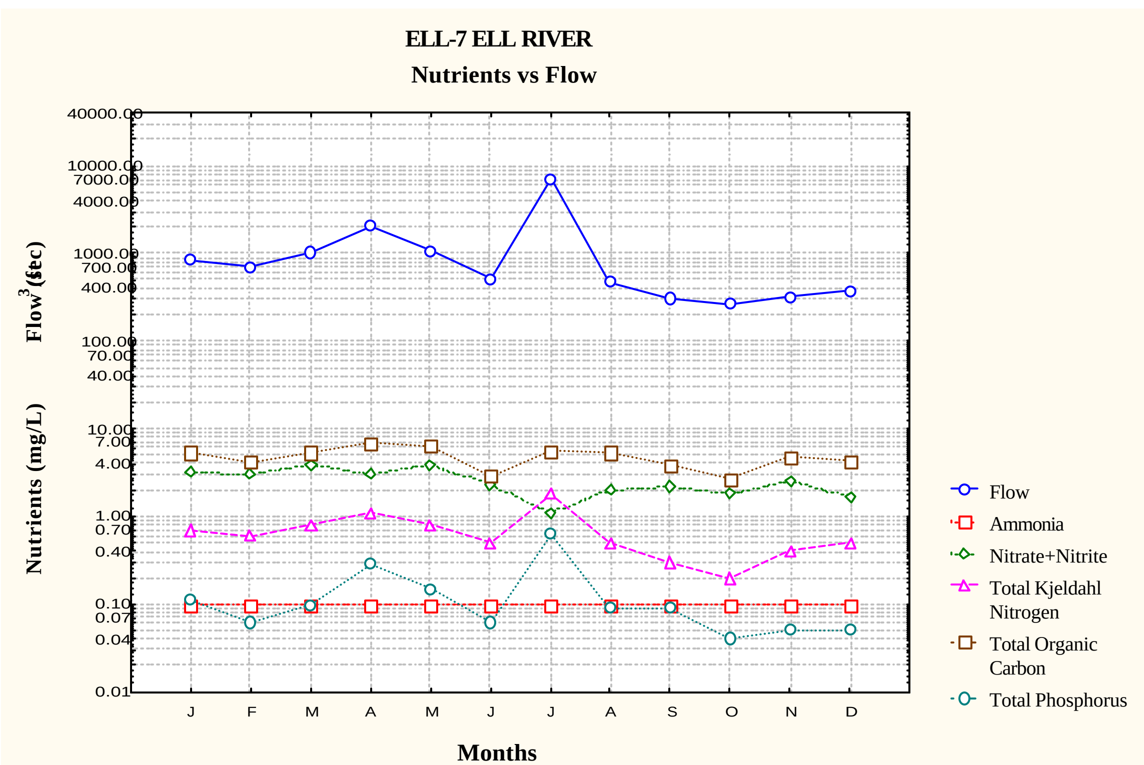




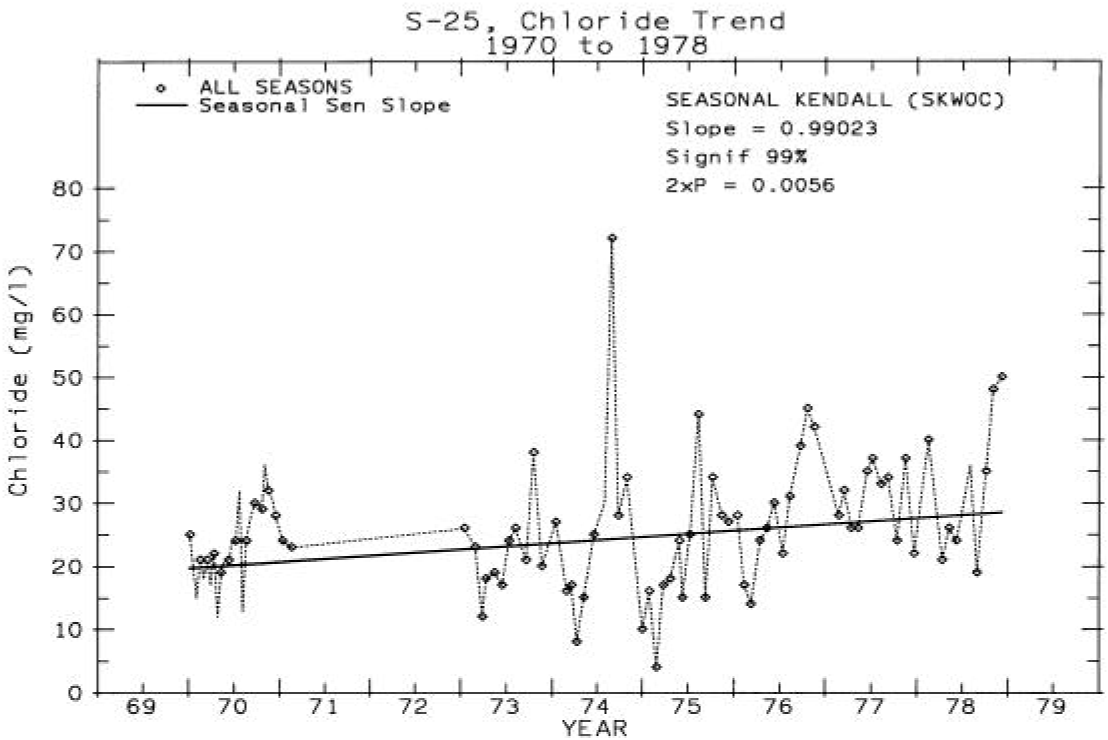

WABASH RIVER TRIBUTARIES
Fixed Station Monitoring Program 1998
Total Phosphorus (mg/L)
0.70
0.55
0.40
0.25
0.10
-0.05
PIP-5
LR-7
ELL-7
ELL-41
ELL-66
DC-5
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

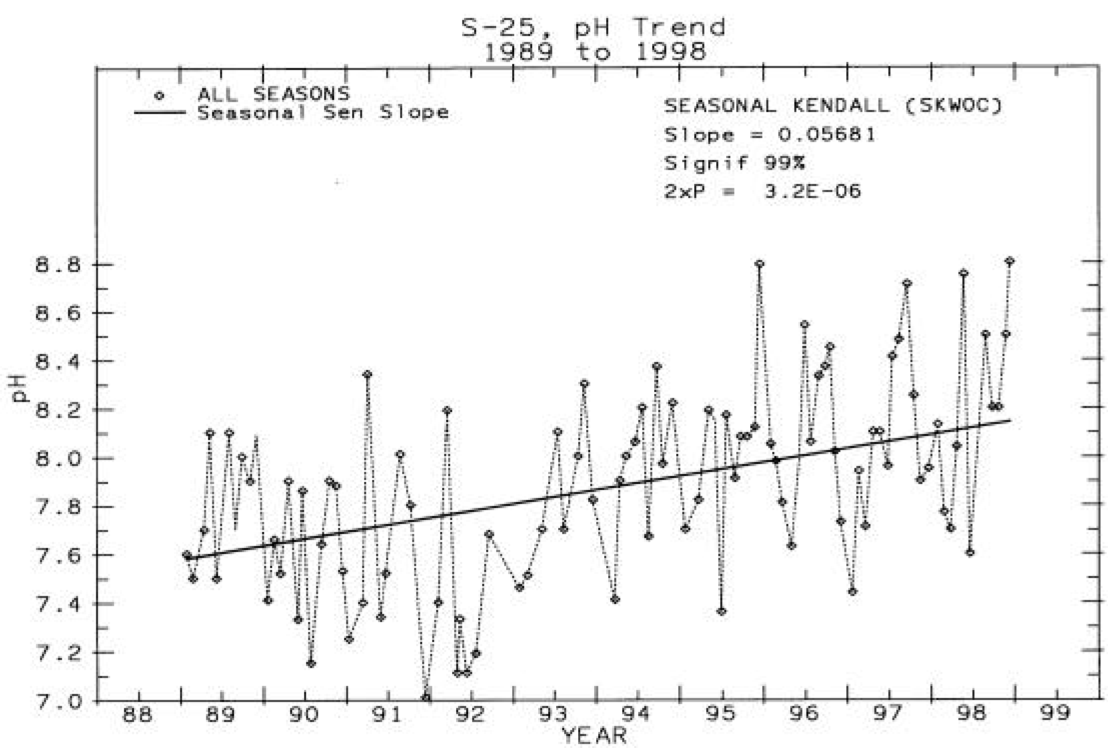

WABASH RIVER TIRBUTARIES
Fixed Station Monitoring Program 1998
Total Organic Carbon (mg/L)
11
9
7
5
3
1
PIP-5
LR-7
ELL-7
ELL-41
ELL-66
DC-5
Station
Non-Outlier Max
Non-Outlier Min
75%
25%
Median
Outliers
Extremes

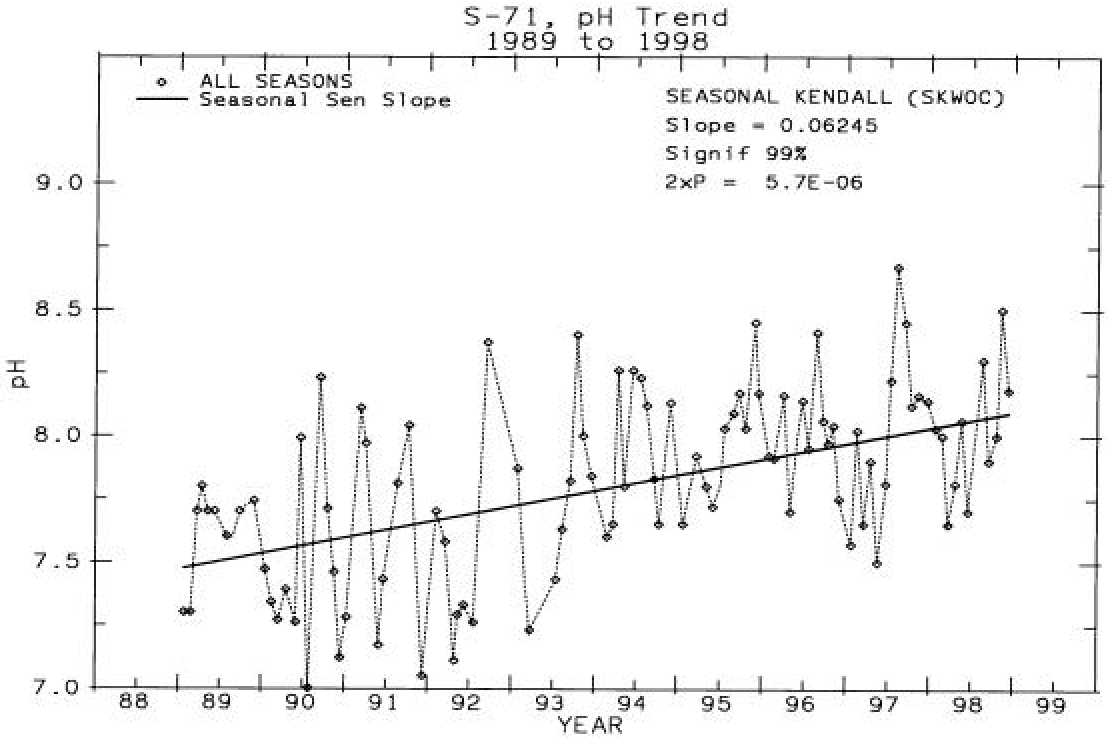

DC-5 DEER CREEK
Nutrients vs Flow
Flow^3(sec)
Nutrients (mg/L)
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

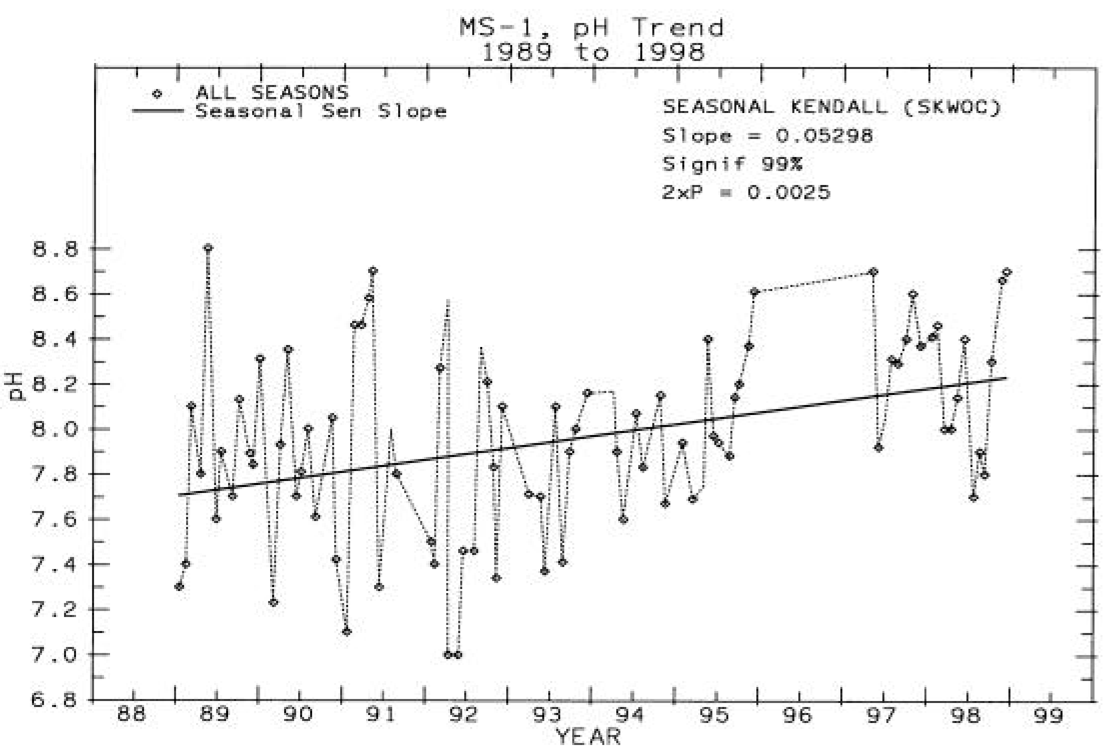

ELL-7 ELL RIVER
Nutrients vs Flow
Flow^3(sec)
Nutrients (mg/L)
40000.00
10000.00
7000.00
4000.00
1000.00
700.00
400.00
100.00
70.00
40.00
10.00
7.00
4.00
1.00
0.70
0.40
0.10
0.07
0.04
0.01
J F M A M J J A S O N D
Months
Flow
Ammonia
Nitrate+Nitrite
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus

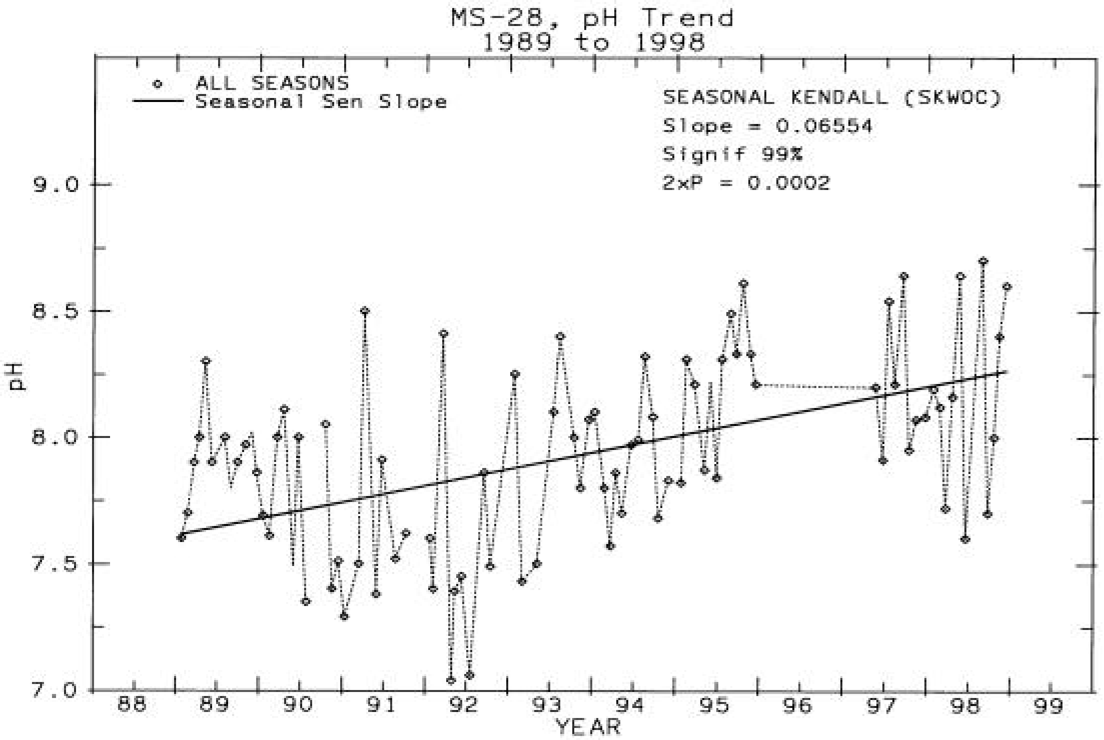
Appendix I Seasonal Kendall Analysis of Selected Water Quality Parameters

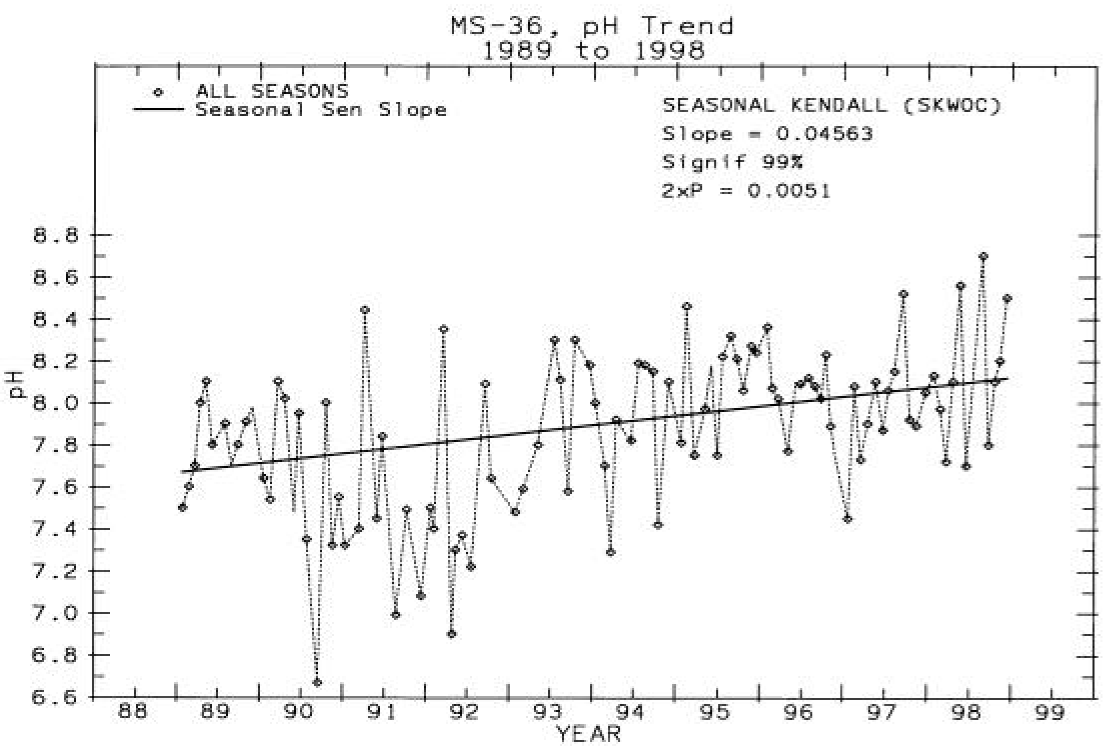


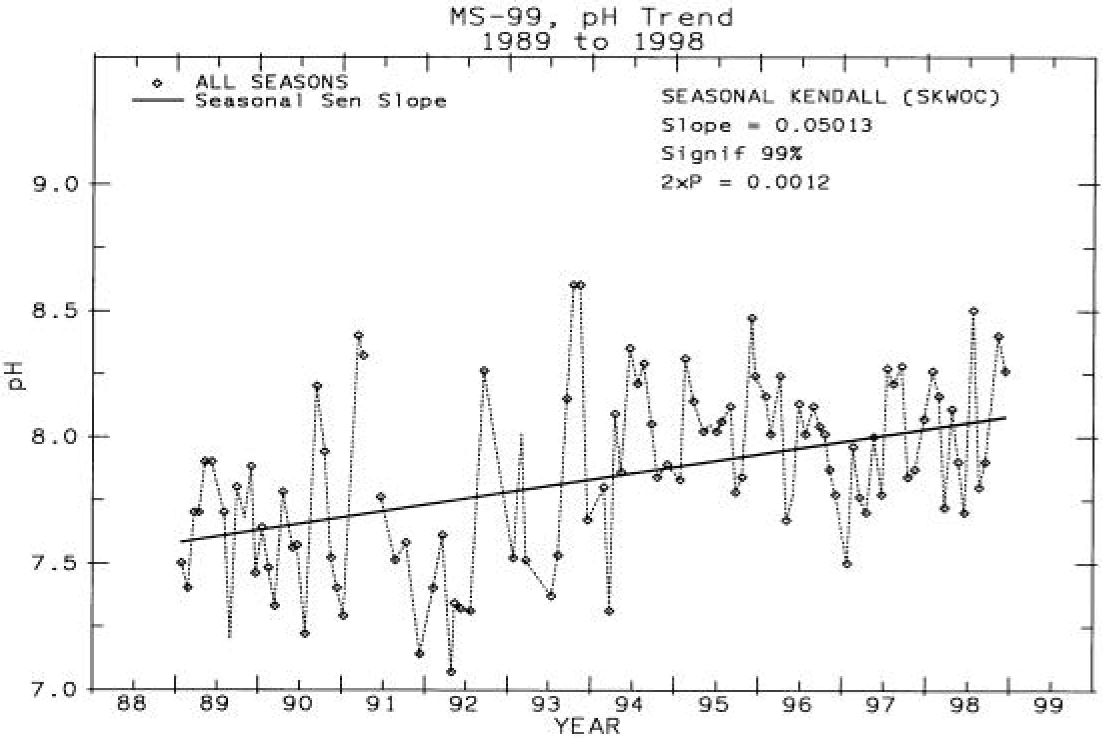


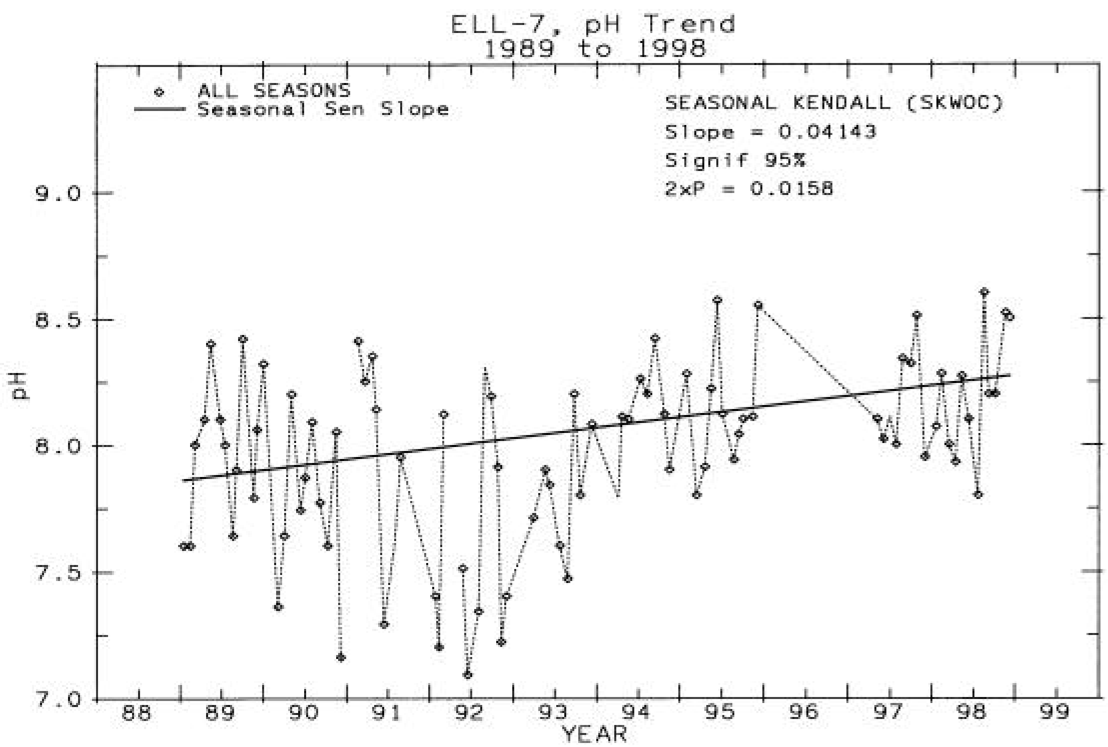

S-71, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.06245
Signif 99%
2xP = 5.7E-06
pH
YEAR

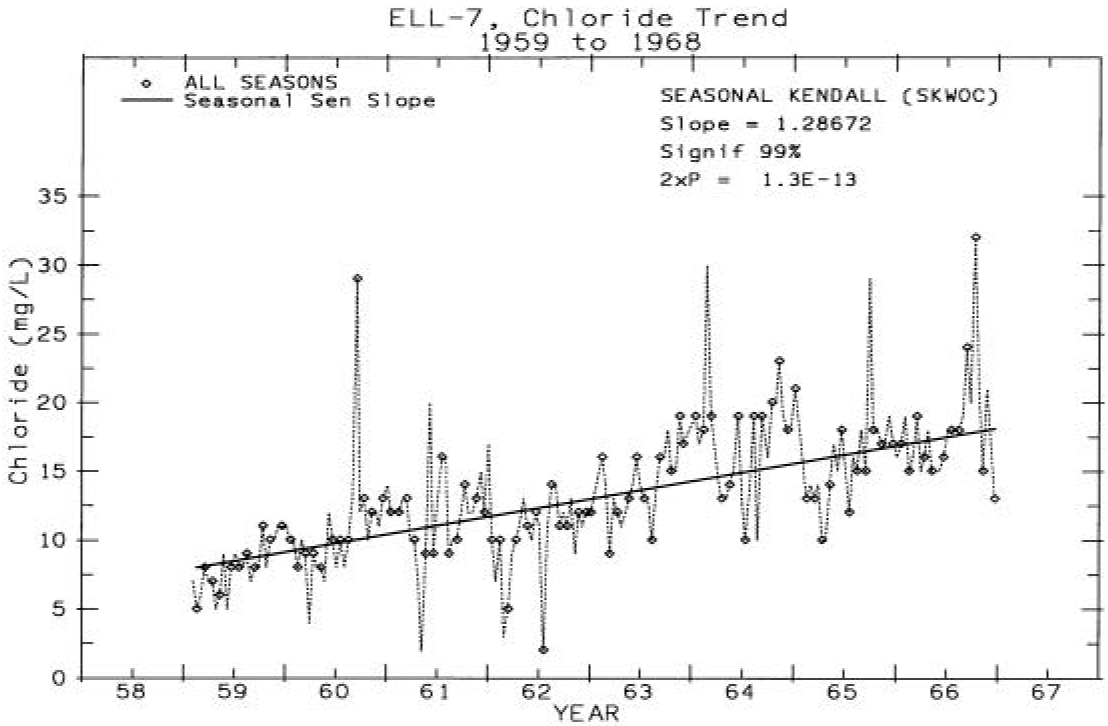

MS-1, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.05298
Signif 99%
2xP = 0.0025
pH
YEAR

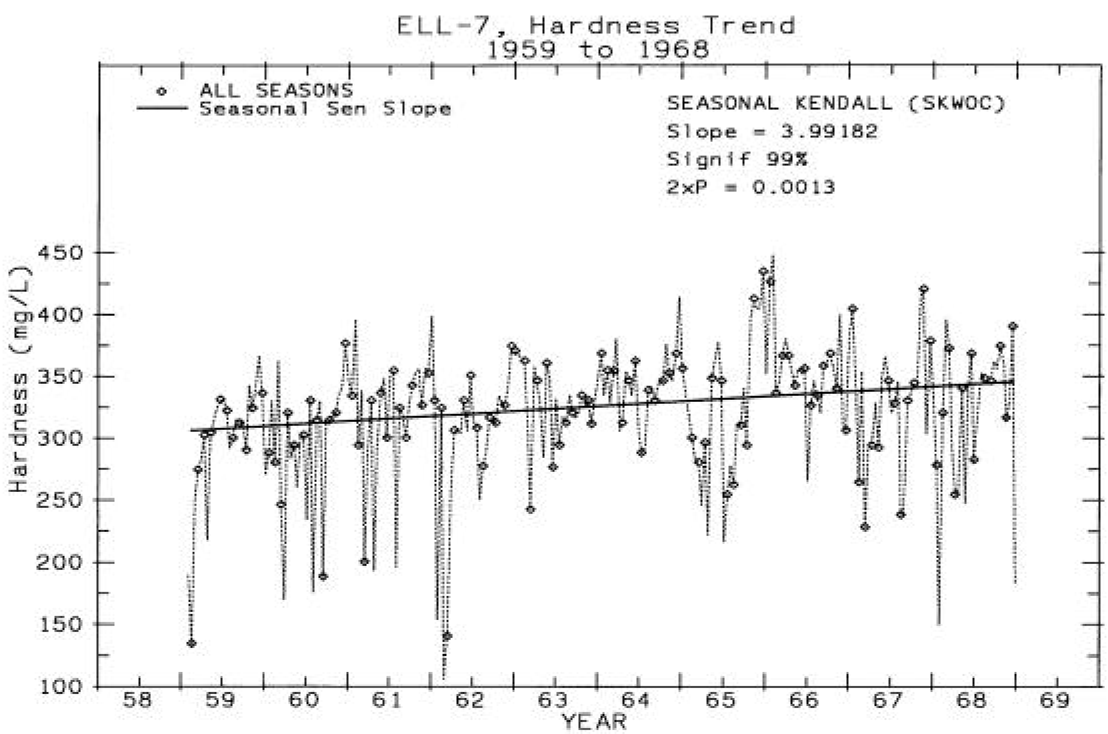

MS-28, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.06554
Signif 99%
2xP = 0.0002
pH
9.0
8.5
8.0
7.5
7.0
88
89
90
91
92
93
94
95
96
97
98
99
YEAR

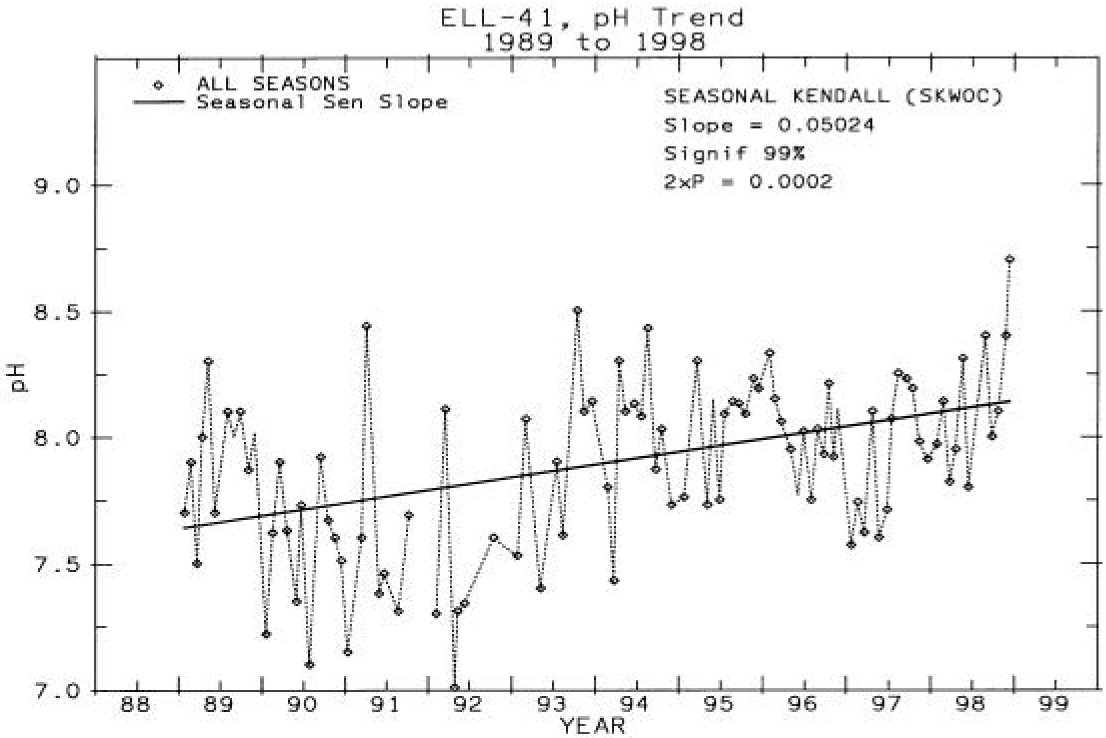

MS-36, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.04563
Signif 99%
2xP = 0.0051
pH
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
88
89
90
91
92
93
94
95
96
97
98
99
YEAR

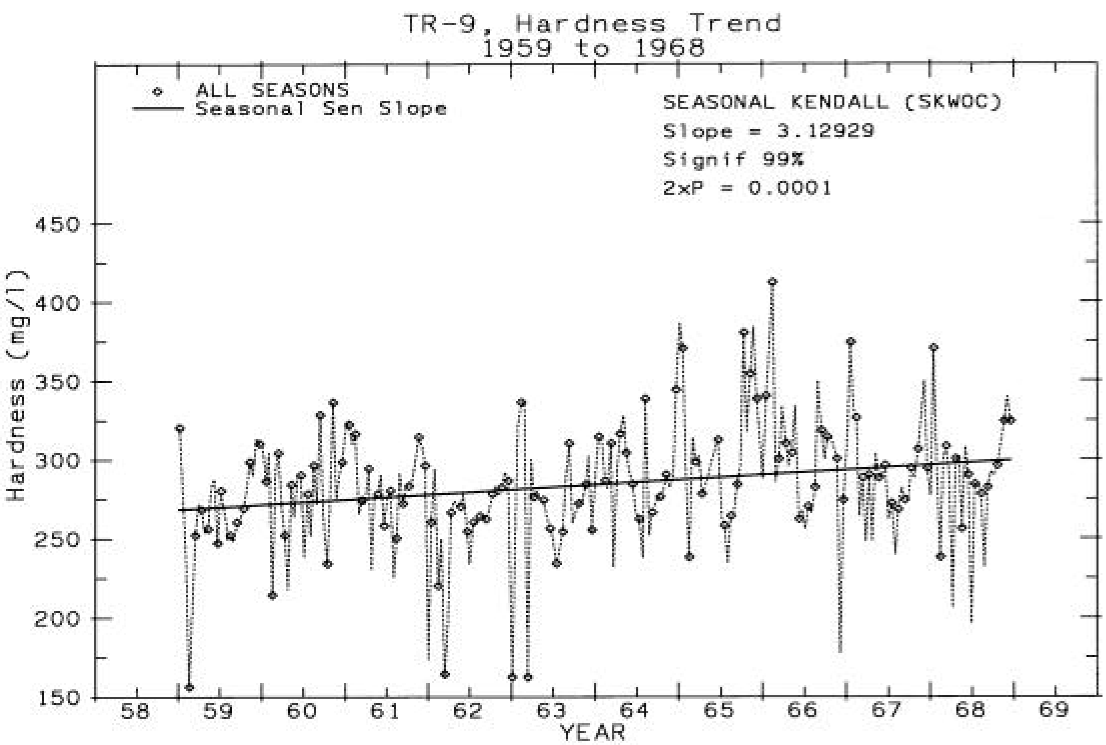

MS-99, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.05013
Signif 99%
2xP = 0.0012
pH
9.0
8.5
8.0
7.5
7.0
88 89 90 91 92 93 94 95 96 97 98 99
YEAR

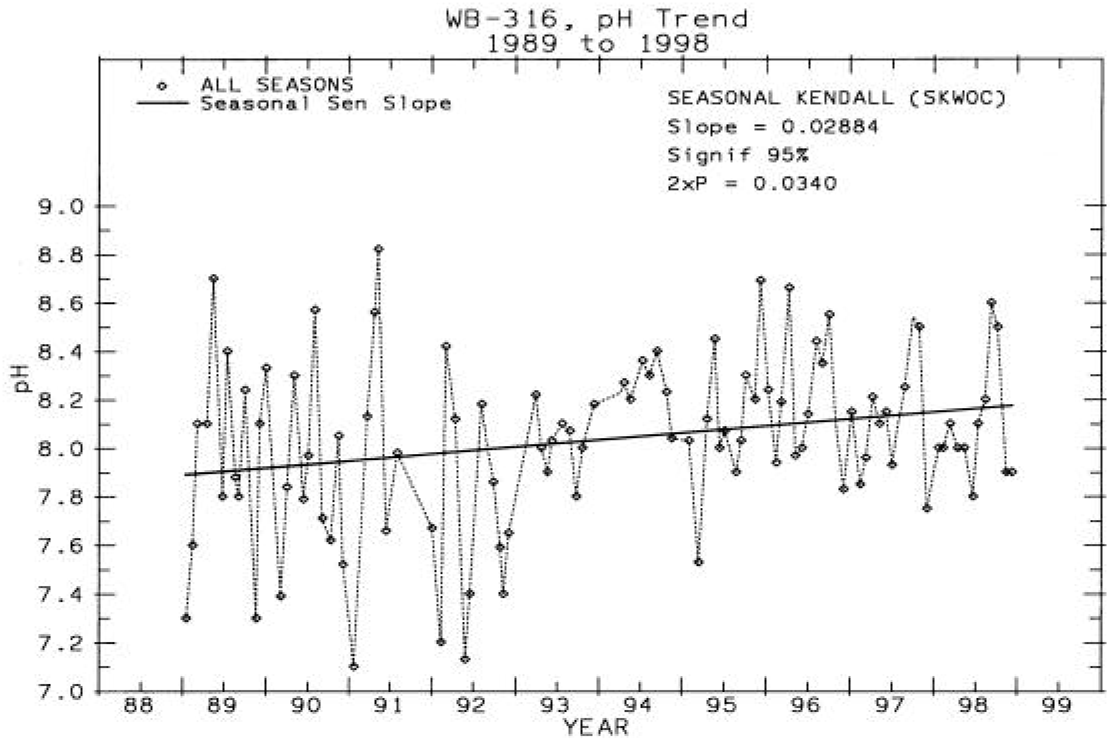

ELL-7, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.04143
Signif 95%
2xP = 0.0158
pH
9.0
8.5
8.0
7.5
7.0
88 89 90 91 92 93 94 95 96 97 98 99
YEAR

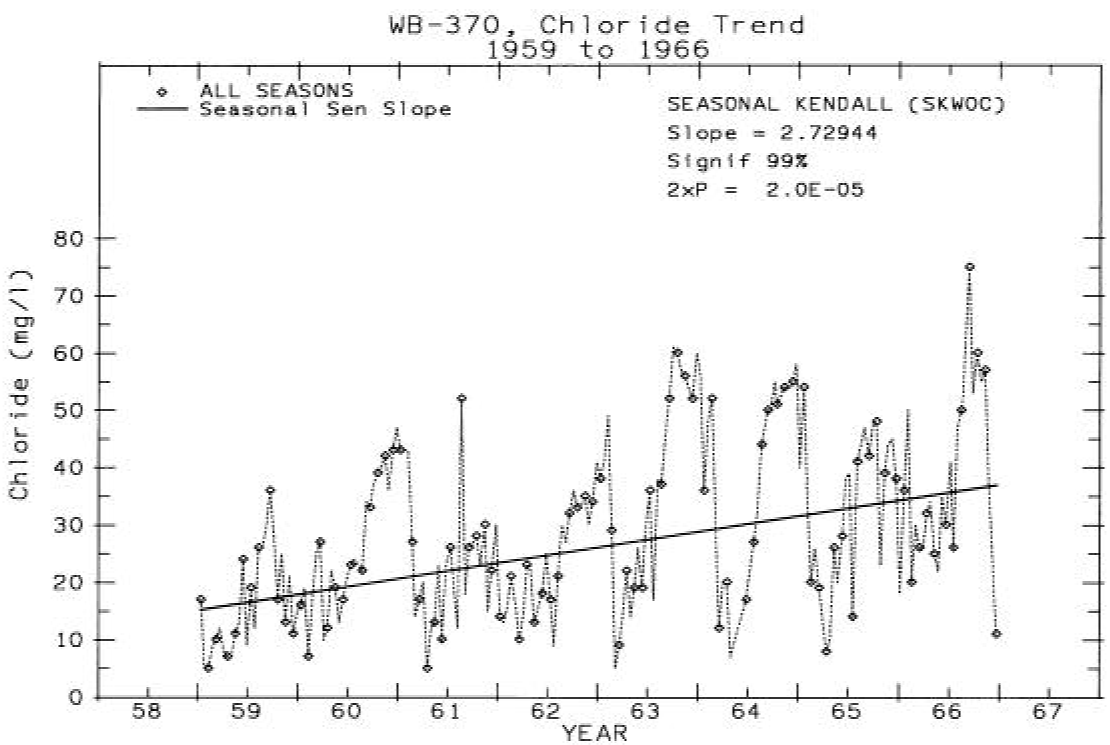

ELL-7, Chloride Trend
1959 to 1968
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 1.28672
Signif 99%
2xP = 1.3E-13
Chloride (mg/L)
0
5
10
15
20
25
30
35
58
59
60
61
62
63
64
65
66
67
YEAR

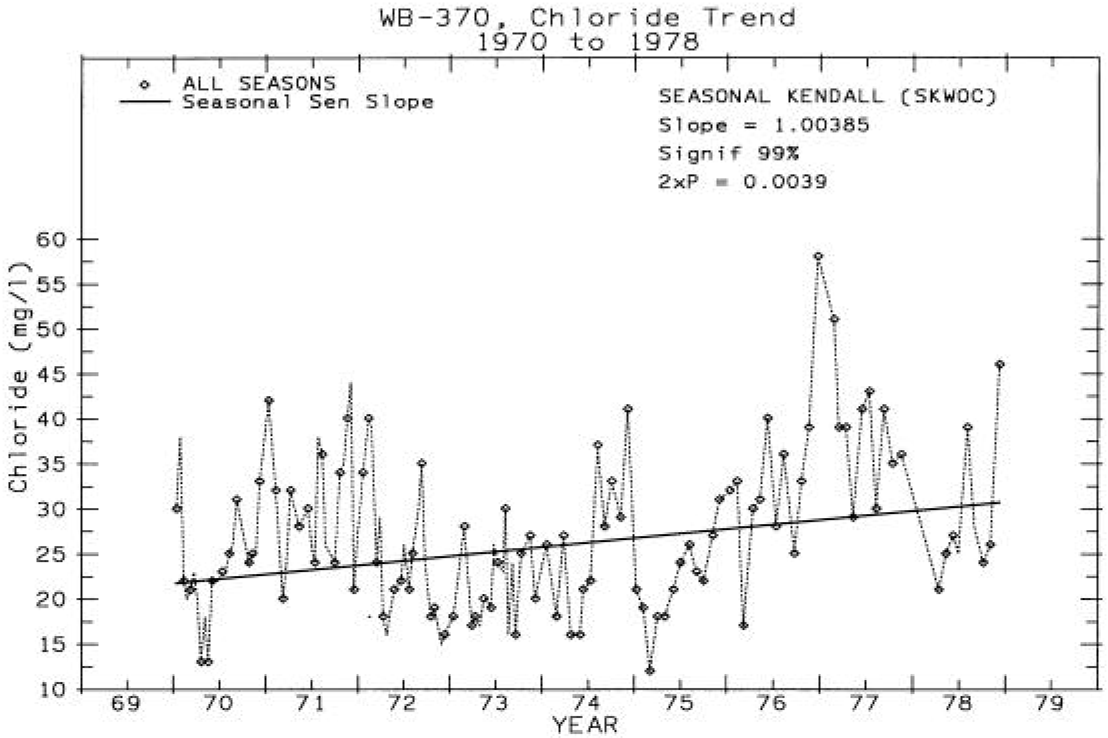

ELL-7, Hardness Trend
1959 to 1968
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 3.99182
Signif 99%
2xP = 0.0013
Hardness (mg/L)
100
150
200
250
300
350
400
450
58
59
60
61
62
63
64
65
66
67
68
69
YEAR

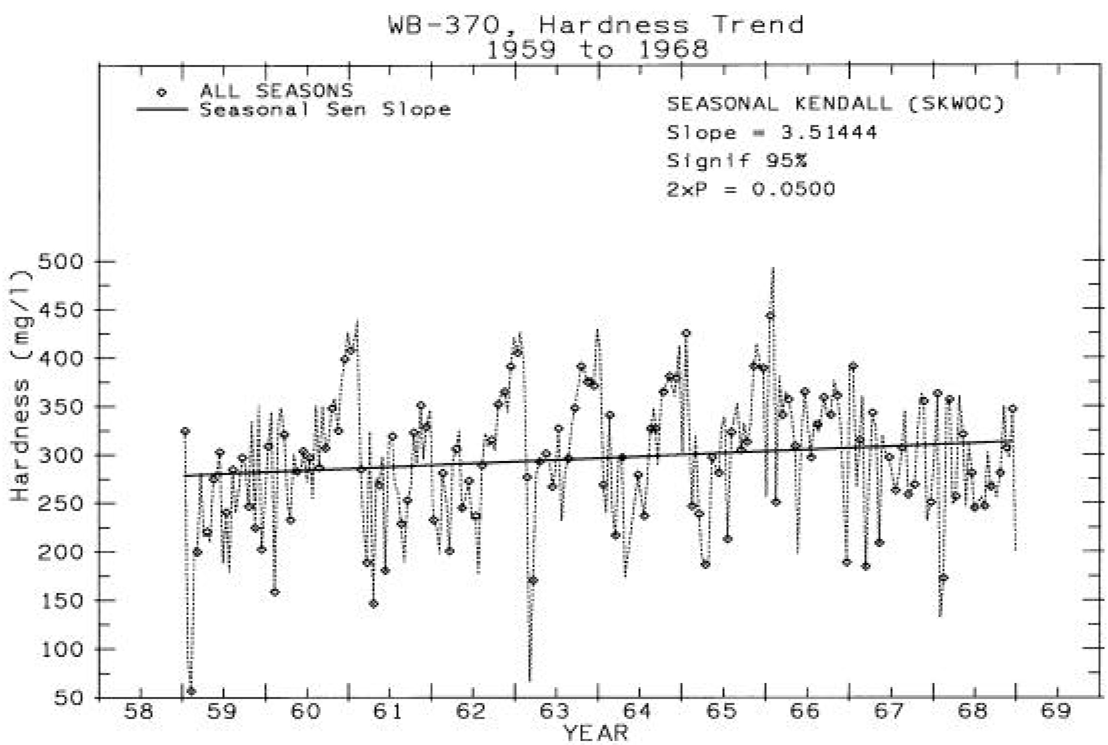

ELL-41, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.05024
Signif 99%
2xP = 0.0002
pH
9.0
8.5
8.0
7.5
7.0
88 89 90 91 92 93 94 95 96 97 98 99
YEAR

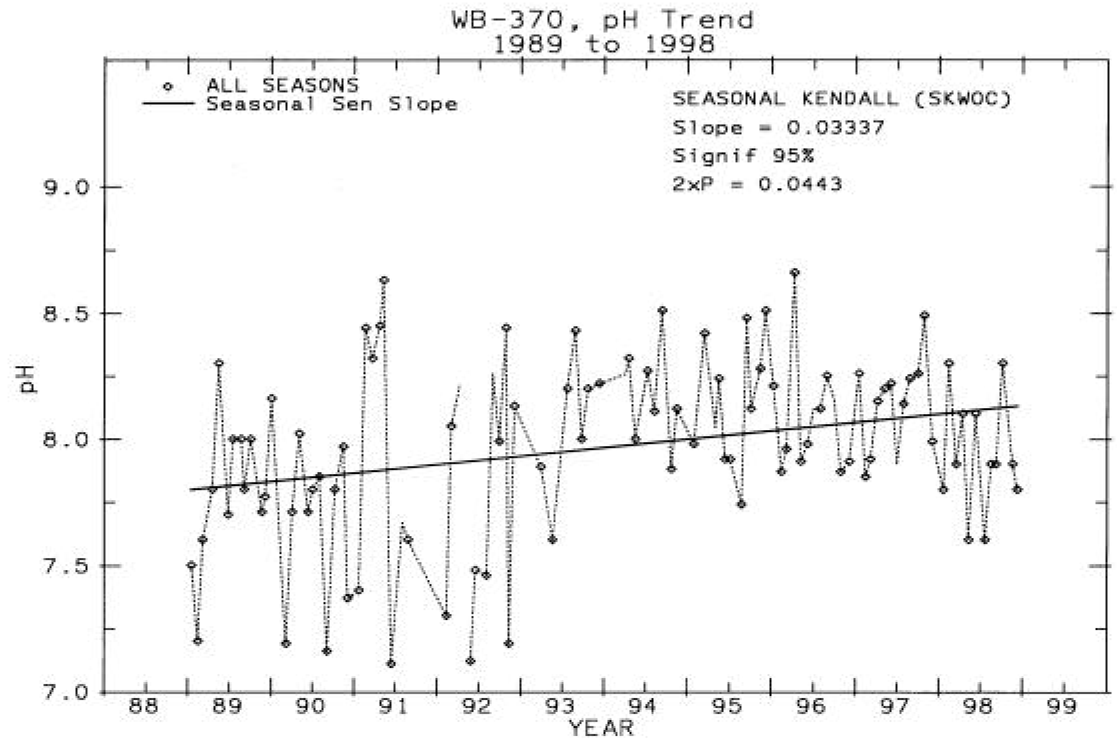

TR-9, Hardness Trend
1959 to 1968
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 3.12929
Signif 99%
2xP = 0.0001
Hardness (mg/l)
450
400
350
300
250
200
150
58 59 60 61 62 63 64 65 66 67 68 69
YEAR

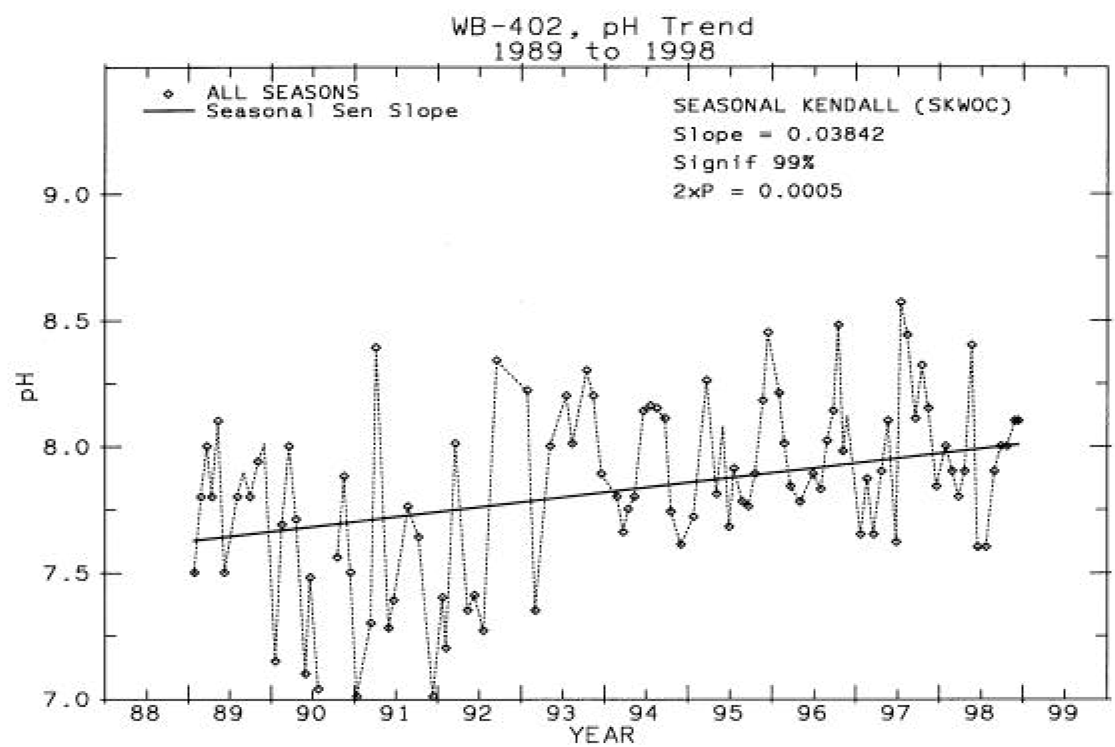

WB-316, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.02884
Signif 95%
2xP = 0.0340
pH
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
88
89
90
91
92
93
94
95
96
97
98
99
YEAR

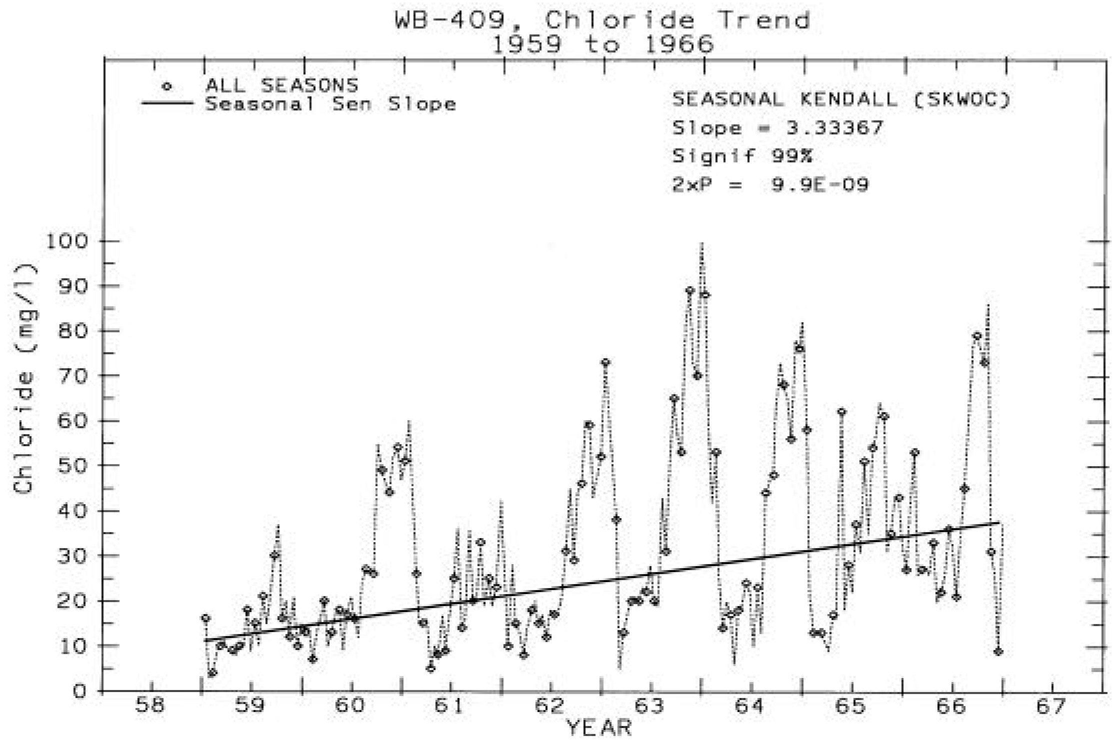

WB-370, Chloride Trend
1959 to 1966
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 2.72944
Signif 99%
2xP = 2.0E-05
Chloride (mg/l)
80
70
60
50
40
30
20
10
0
58
59
60
61
62
63
64
65
66
67
YEAR

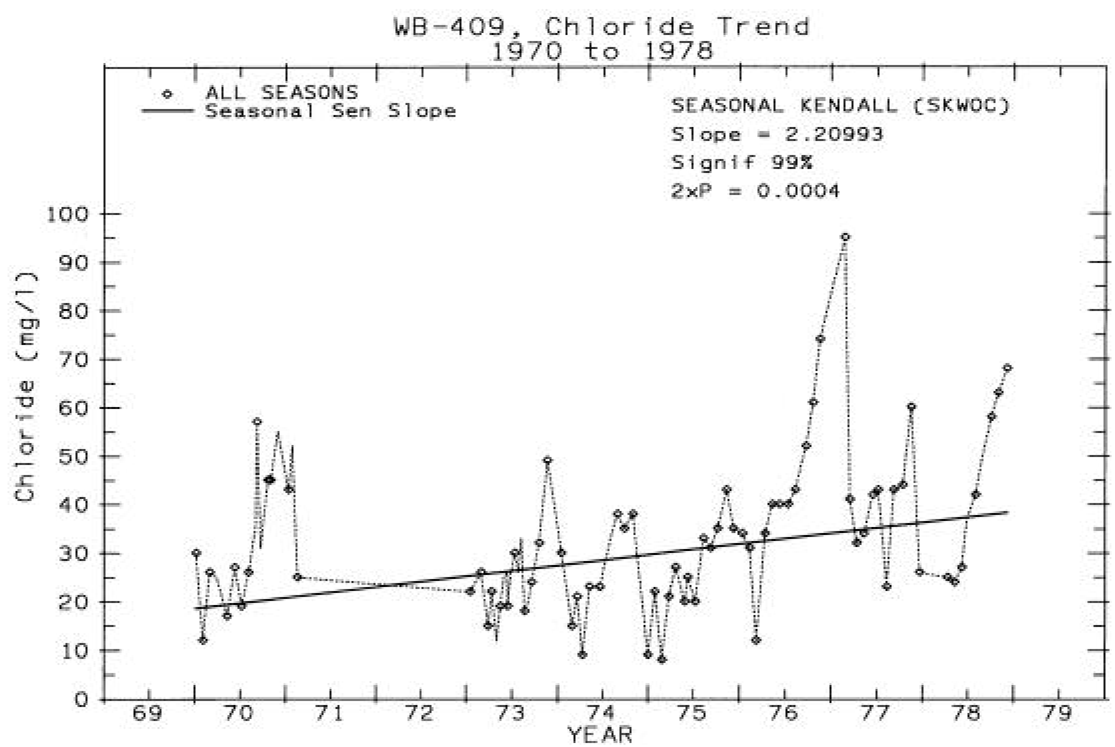

WB-370, Chloride Trend
1970 to 1978
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 1.00385
Signif 99%
2xP = 0.0039
Chloride (mg/l)
60
55
50
45
40
35
30
25
20
15
10
69
70
71
72
73
74
75
76
77
78
79
YEAR

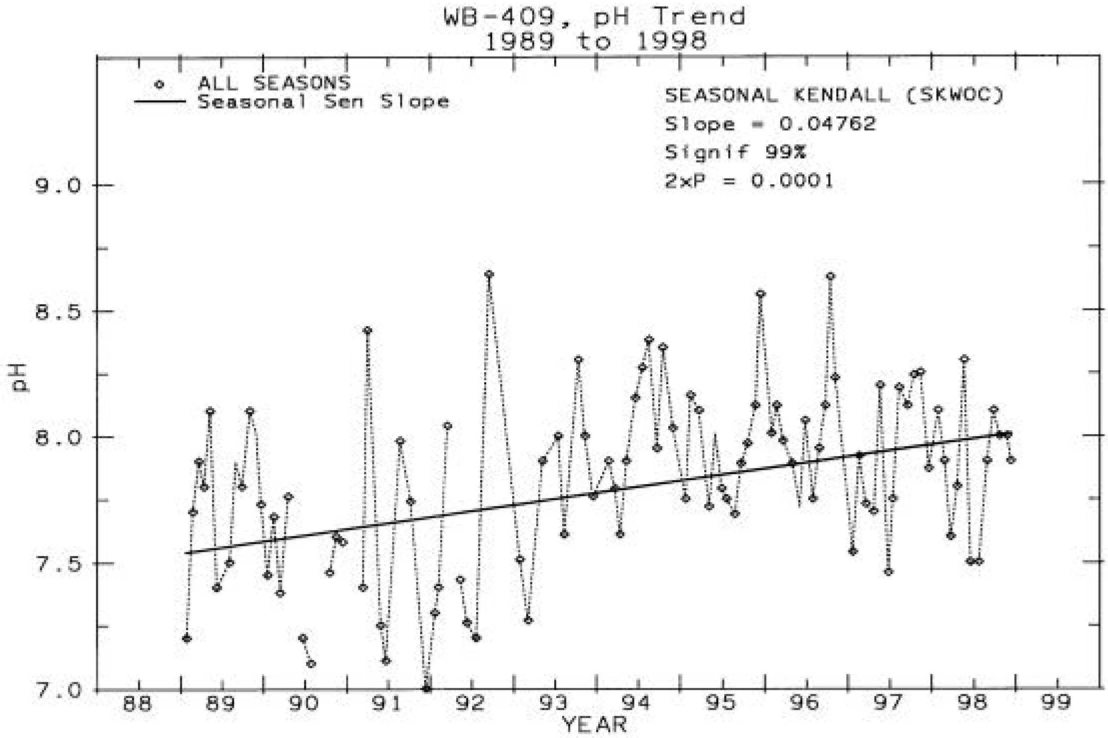

WB-370, Hardness Trend
1959 to 1968
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 3.51444
Signif 95%
2xP = 0.0500
Hardness (mg/l)
500
450
400
350
300
250
200
150
100
50
58
59
60
61
62
63
64
65
66
67
68
69
YEAR

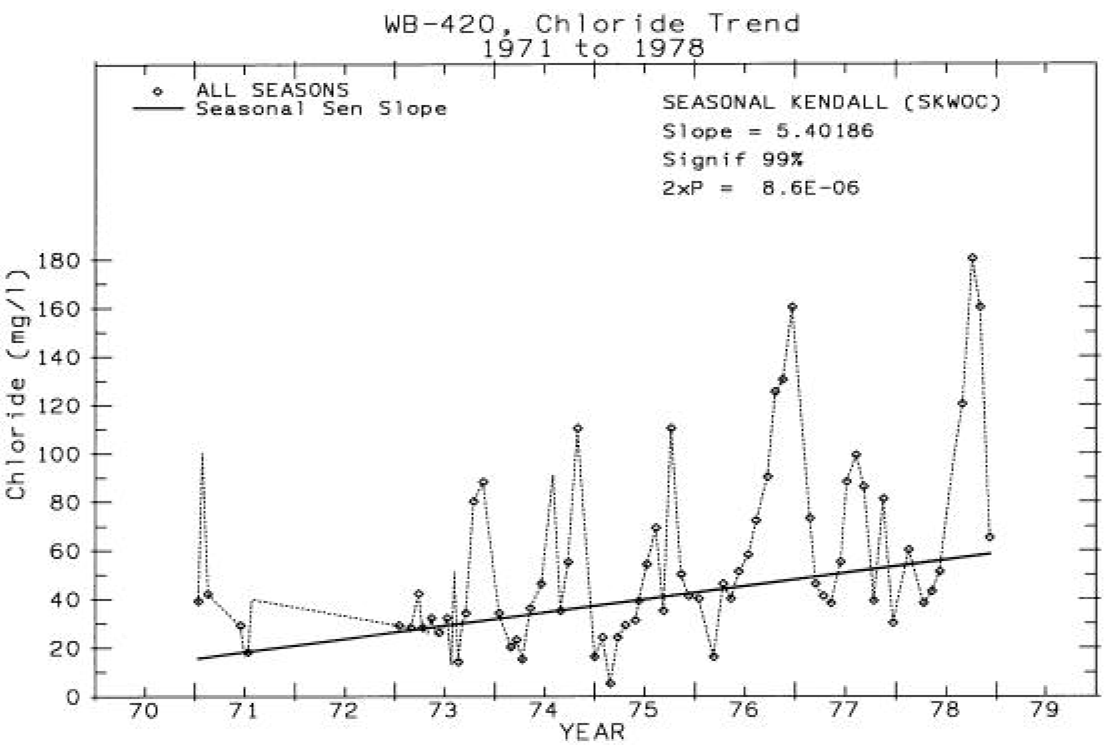

WB-370, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.03337
Signif 95%
2xP = 0.0443
pH
9.0
8.5
8.0
7.5
7.0
88
89
90
91
92
93
94
95
96
97
98
99
YEAR

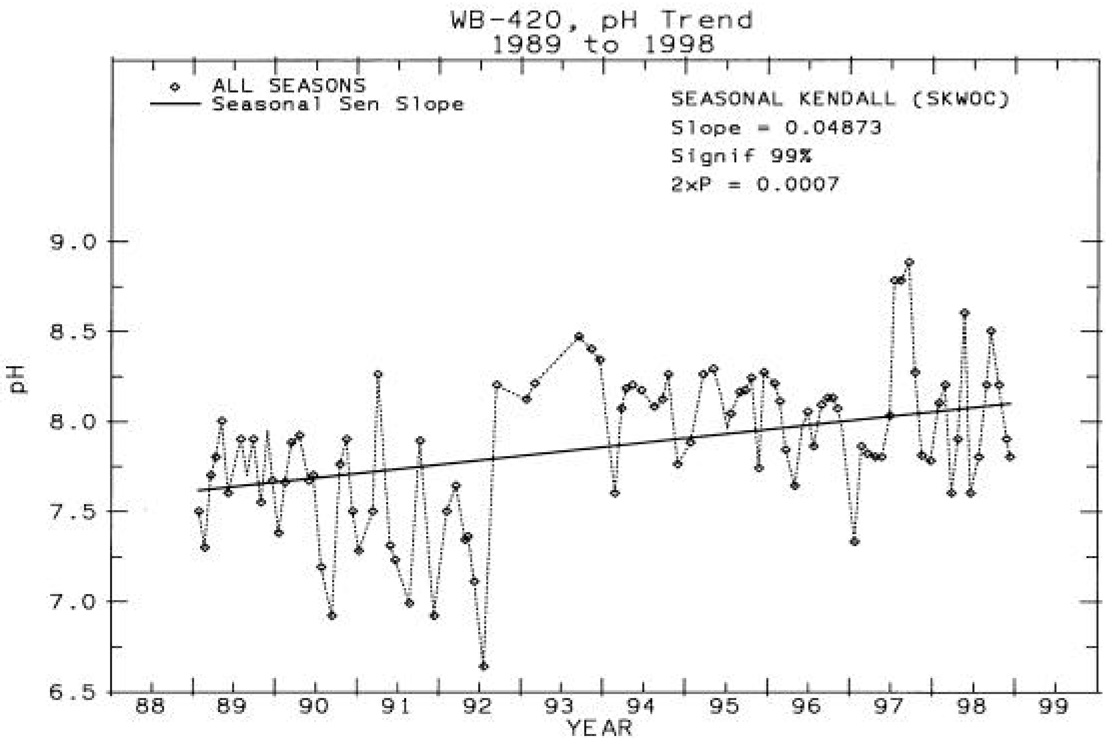

WB-402, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.03842
Signif 99%
2xP = 0.0005
pH
9.0
8.5
8.0
7.5
7.0
88
89
90
91
92
93
94
95
96
97
98
99
YEAR

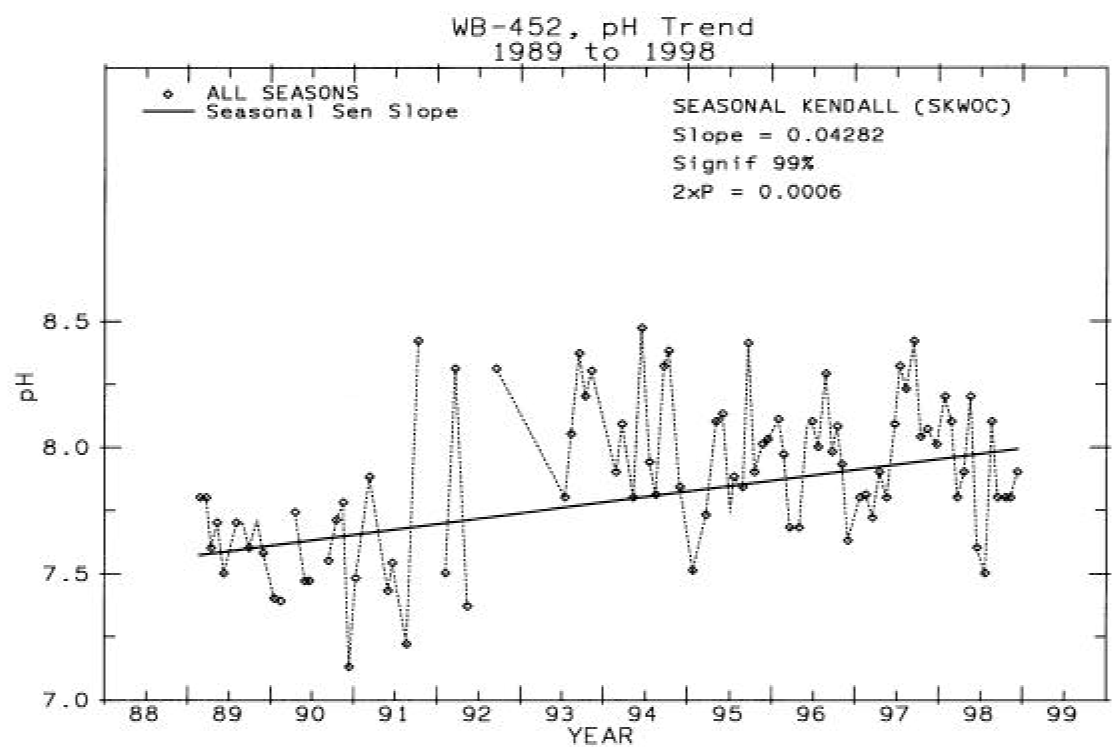

WB-409, Chloride Trend
1959 to 1966
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 3.33367
Signif 99%
2xP = 9.9E-09
Chloride (mg/l)
YEAR


WB-409, Chloride Trend
1970 to 1978
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 2.20993
Signif 99%
2xP = 0.0004
Chloride (mg/l)
YEAR


WB-409, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.04762
Signif 99%
2xP = 0.0001
pH
9.0
8.5
8.0
7.5
7.0
88
89
90
91
92
93
94
95
96
97
98
99
YEAR


WB-420, Chloride Trend
1971 to 1978
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 5.40186
Signif 99%
2xP = 8.6E-06
Chloride (mg/l)
180
160
140
120
100
80
60
40
20
0
70
71
72
73
74
75
76
77
78
79
YEAR


WB-420, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.04873
Signif 99%
2xP = 0.0007
pH
9.0
8.5
8.0
7.5
7.0
6.5
88 89 90 91 92 93 94 95 96 97 98 99
YEAR


WB-452, pH Trend
1989 to 1998
ALL SEASONS
Seasonal Sen Slope
SEASONAL KENDALL (SKWOC)
Slope = 0.04282
Signif 99%
2xP = 0.0006
pH
8.5
8.0
7.5
7.0
88 89 90 91 92 93 94 95 96 97 98 99
YEAR